

Field Sampling Plan

for

Upper and Lower Silver Creek Summit County, Utah

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Prepared for:

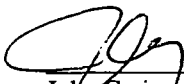
U.S. Environmental Protection Agency Region 8
1595 Wynkoop Street
Denver, CO 80202

Prepared by:

Tetra Tech, Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 22030

May 15, 2008
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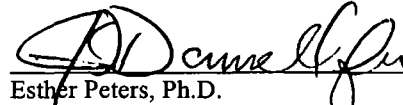
Approvals:



John Craig
Task Order Leader
Tetra Tech, Inc.

5/21/08

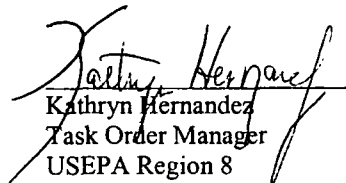
Date



Esther Peters, Ph.D.
Quality Assurance Manager
Tetra Tech, Inc.

5/21/08

Date



Kathryn Hernandez
Task Order Manager
USEPA Region 8

5/21/08

Date

Anthony Medrano
QA Officer
USEPA Region 8

Date

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10306 Eaton Place, Suite 340
Fairfax, VA 22030

May 30, 2008
FSP QA No. 170 Revision 1

Approvals:

John Craig
Work Assignment Leader
Tetra Tech, Inc.

Date

Esther Peters, Ph.D.
Quality Assurance Manager
Tetra Tech, Inc.

Date

Kathryn Hernandez
Work Assignment Manager
USEPA Region 8

Date

~~Tom Brooks~~
QA Manager
USEPA Region 8

Date

Tony Medrano 6.2.08
~~Tom Brooks~~ TONY MEDRANO

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Quality Assurance Manager
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Work Assignment Manager
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Tom Brooks
QA Manager
USEPA Region 8

Date

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DISTRIBUTION

This document will be distributed to the following at the U.S. Environmental Protection Agency, Region 8, Utah Department of Environmental Quality and Tetra Tech, Inc., staff who are involved in this project.

Name Title	Phone Fax E-mail	Mailing Address
U.S. Environmental Protection Agency Region 8		
Kathryn Hernandez Task Order Manager	303-312-6101 (phone) 303-312-6897 (fax) hernandez.kathryn@epa.gov	US Environmental Protection Agency Region 8 999 18th Street Denver, CO 80202
Tom Brooks Quality Assurance Manager	303-312-6336 (phone) 303-312-7828 (fax) brooks.tom@epa.gov	
Utah Department of Environmental Quality		
Kari Lundeen TMDL/Watershed Coordinator	801-538-6760 (phone) (fax) klundeen@utah.gov	UDEQ/Division of Water Quality P.O. Box 144870 Salt Lake City, UT 84114
Mo Slam	801-536-4178 (phone) (fax) mslam@utah.gov	UDEQ/DERR 168 N 1950 W Salt Lake City, UT 84114
Tetra Tech, Inc.		
John Craig Task Order Leader	703-385-6000 (phone) 703-385-6007 (fax) john.craig@tetrattech.com	Tetra Tech, Inc. 10306 Eaton Place, Suite 340 Fairfax, VA 22030
Jon Ludwig Co-Task Order Leader	304-414-0054 (phone) 304-720-2334 (fax) jon.ludwig@tetrattech.com	Tetra Tech, Inc. 405 Capitol Street, Suite 608 Charleston, WV 25301
Mike Egan Utah Team Leader	801-364-1064 (phone) 801-538-6016 (fax) mike.egan@tetrattech.com	Tetra Tech, Inc. 136 East South Temple, Suite 910 Salt Lake City, UT 84111
Chris Hayes Technical Support	801-364-1064 (phone) 801-538-6016 (fax) chris.hayes@tetrattech.com	
John O'Donnell QC Officer	703-385-6000 (phone) 703-385-6007 (fax) john.odonnell@tetrattech.com	Tetra Tech, Inc. 10306 Eaton Place, Suite 340 Fairfax, VA 22030
Esther Peters, Ph.D. Quality Assurance Manager	703-385-6000 (phone) 703-385-6007 (fax) esther.peters@tetrattech.com	

Name Title	Phone Fax E-mail	Mailing Address
Sam Wilkes Co-Sampling Team Leader	304-414-0054 (phone) 304-720-2334 (fax) sam.wilkes@tetrattech.com	Tetra Tech, Inc 405 Capitol Street, Suite 608 Charleston, WV 25301
John Beckman Co-Sampling Team Leader	304-414-0054 (phone) 304-720-2334 (fax) john.beckman@tetrattech.com	
Analytical Laboratory (EPA Region 8 CLP and additional parameters)		
EPA Region 8 CLP Lab DataChem Laboratory Kevin Griffiths (Project Manager)	1-800-356-9135 (phone) 801-266-7700 (phone) 801-268-9992 (fax)	DataChem Laboratories, Inc. 960 West LeVoy Drive Salt Lake City, Utah 84123

1.0 INTRODUCTION AND BACKGROUND

This Field Sampling Plan (FSP) supports the field work performed by Tetra Tech as a contractor of the EPA in the Upper and Lower Silver Creek corridor for the Silver Creek Load Reduction Alternatives Assessment. Tetra Tech is performing this work for the Environmental Protection Agency (EPA) under Contract Number EP-C-05-046. The field activities will be performed during spring of 2008.

Following guidance provided in 40 CFR § 300.430(b)(8)(i) and (ii), this FSP represents one of the two documents that comprise the Sampling and Analysis Plan (SAP) covering Tetra Tech's field work. The FSP provides guidance for field personnel by defining, in detail, the number, type, and location of samples to be collected; and the type of analyses to be performed. This FSP follows the general guidelines for development of field sampling plans presented in EPA (1988). This FSP is intended to be used with the companion Quality Assurance Project Plan (QAPP). The QAPP describes the policy, organization, functional activities, and quality assurance and quality control protocols employed to verify that the data and measurements collected achieve the specified data quality objectives. This FSP was developed for the use of Tetra Tech and approved Tetra Tech contractors. The companion QAPP document was developed by the Utah Department of Environmental Quality, Division of Environmental Response and Remediation (UDEQ DERR) and approved by EPA Region VIII personnel.

Tetra Tech will provide the majority of the technical and field staff to perform the sampling and reporting aspects of the individual tasks related to this work. Tetra Tech will subcontract with qualified subcontractors to perform the following specific tasks:

- Additional analytical suite parameters for surface water will also be analyzed by DataChem Laboratories, Inc of Salt Lake City, Utah
- Additional analytical suite includes: Ferrous (Iron^{+2}), Ferric (Iron^{+3}), Sulfate, and Dissolved Organic Carbon

An approved EPA Contract Laboratory Program (CLP) facility (DataChem Laboratory in Salt Lake City, Utah) will perform inorganic surface water, groundwater, and sediment analyses on the samples collected by Tetra Tech personnel.

1.1 Project/Task Organization

The organizational aspects of a program provide the framework for conducting tasks. The organizational structure and function can also facilitate project performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key project roles are filled by those persons responsible for ensuring the collection of valid data and the routine assessment of the data for precision and accuracy, as well as the data users and the person(s) responsible for approving and accepting final products and deliverables. The program organizational chart is presented in Figure 1 and includes relationships and lines of communication among all participants and data users. The responsibilities of these persons are described below. Kathryn Hernandez, USEPA, Region 8, is providing overall project/program oversight for this study as the Work Assignment Manager (WAM). She will supervise the assigned project personnel to

provide for their efficient utilization by directing their efforts either directly or indirectly. The WAM will also have the following responsibilities:

- Providing oversight for study design, site selection, and adherence to design objectives.
- Reviewing and approving the project work plan, FSP, and other materials developed to support the project.
- Coordinating with contractors, reviewers and others to ensure technical quality and contract adherence.

The EPA Region 8 Quality Assurance Manager is Tom Brooks, who will be responsible for reviewing and approving the FSP. Additional EPA QA Manager responsibilities include the following:

- Reviewing and evaluating field procedures.
- Conducting external performance and system audits of the procedures.
- Participating in Agency QA reviews of the study.

John Craig and Jon Ludwig, the Tetra Tech Co-Work Assignment Leaders (WAL), will manage all technical aspects of the project. Their specific responsibilities include:

- Coordinating project assignments in establishing priorities and scheduling.
- Ensuring completion of high-quality deliverables within established budgets and time schedules.
- Providing guidance, technical advice, and performance evaluations to those assigned to the project.
- Implementing corrective actions and providing professional advice to staff.
- Reviewing project deliverables, including the FSP, and draft and final reports.

Esther Peters, Tetra Tech QA Officer, or her designee, will assist the WALs and is independent of the field, laboratory, data, and reporting activities. Major responsibilities include:

- Monitoring QC activities to determine conformance.
- Providing support to the Tetra Tech WALs in preparation of the FSP, and their distribution.
- Reviewing and approving the FSP.

The Tetra Tech Co-Sampling Team Leaders, Sam Wilkes and John Beckman, will be responsible for managing specific tasks during the project (i.e., performing field sampling, and collecting physical, chemical, and biological water quality data). The Sampling Team Leaders will supervise the technical staff participating in their group and their activities, implementing the QC program, completing assigned work on schedule with strict adherence to procedures established in the approved FSP, and completing required documentation. The Sampling Team Leaders will direct the work of the field sampling team, including collection, preparation, and shipment of samples and completion of field sampling records. The field sampling team will include scientific staff with specialization and technical competence in field sampling activities and specialized habitat assessment to effectively and efficiently perform the required work. Mike Egan, Chris Hayes and other technical staff from the Salt Lake City office may provide additional field assistance as needed. They must perform all work in adherence with the project work plan and approved FSP, including maintenance of sample custody and related documentation. Custody procedures are required to ensure the integrity of the samples with respect to prevention of contamination and maintenance of proper sample identification during handling. In this role, the field sampling team is responsible for:

- Receiving and inspecting the sample containers.
- Completing and signing appropriate field records.
- Assigning tracking numbers to each sample.
- Verifying the completeness and accuracy of chain-of-custody documentation.
- Controlling and monitoring access to samples while in their custody.
- Initiating shipment of the samples to appropriate destinations.

Additional oversight will be provided by the Tetra Tech QC Officer, John O'Donnell, who is responsible for performing evaluations to ensure that QC is maintained throughout the sampling process, that the data collected will be of optimal validity and usability, and that limitations of the data set are minimized as much as is possible given the logistical and scheduling challenges of the remote site locations. The QC Officer or his designee will ensure perform QC evaluations, which will include double-checking work as it is completed and providing written documentation of these reviews to ensure that the standards set forth in the FSP are met or exceeded. Other QA/QC Staff, such as technical reviewers and technical editors selected as needed, will provide peer review oversight on the content of work products and ensure that work products comply with client specifications, respectively.

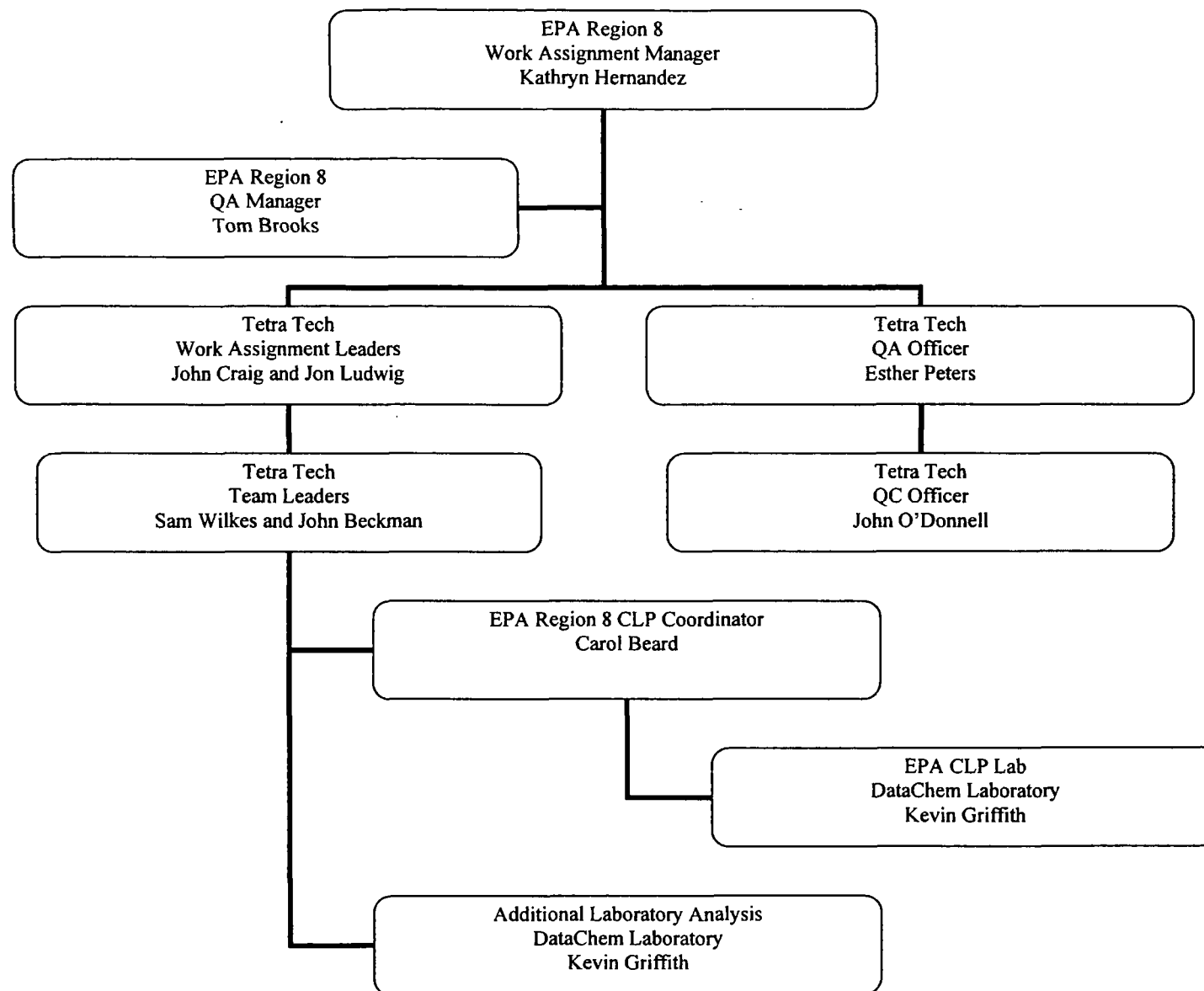


Figure 1-1: Project Organization Chart

An EPA CLP contractor (DataChem Laboratory in Salt Lake City, Utah) is responsible for the inorganic groundwater, surface water and sediment analyses for total and dissolved metals under their existing CLP contract. Tetra Tech will also submit additional samples to DataChem for analyses that are not routinely covered under the CLP contract.

1.2 Background

Silver Creek is located in Summit County, Utah. Silver Creek flows from the headwaters located upstream of Park City into the Weber River, near Wanship, Utah. Silver Creek is fed by precipitation (snowmelt), groundwater, springs, and mine tunnel discharges near the headwaters. This project addresses an approximately 12.25 mile reach of Upper Silver Creek and Lower Silver Creek from the headwaters to I-80 (Figure 1-2). The Upper Silver Creek watershed is located in the headwaters of Empire Canyon and Ontario Canyon. Ontario Canyon flows into Silver Creek near the southern portion of Park City. Silver Creek flows through rapidly developing areas of Park City including the Prospector Square section of town. The stream then picks up water from the confluence with Dority Spring and then flows through a wide riparian area and wetlands near the Silver Maple Claims area toward the Floodplain Tailings and Richardson Flat. The stream begins its transition to a low gradient valley surrounded by small hills, which has traditionally been called Lower Silver Creek (LSC) in previous reports and studies. LSC begins around the Richardson Flat area near Highway 248 and flows through the wide riparian wetland between US 40 toward the West and the Rail Trail toward the East. The project area includes the floodplain and riparian habitat and upland areas adjacent to Silver Creek. The LSC portion is up to 3,800 ft wide. The region is currently undergoing significant development.

Silver Creek is designated for beneficial use Class 3A for protection of cold water fish and cold water species (UDEQ - DWQ, 2004). Water rights for domestic water, stock, irrigation, and recreation are held by public and private entities. LSC is flood irrigated and the stream is impacted by irrigation runoff and groundwater return flows. Several irrigation ditches have been constructed in the basin. US Geological Survey (USGS) stream flow gauging station 10129900 is located within the LSC Site downstream of the Snyderville Water Reclamation Facility outfall.

Mining in the Park City area began around 1869. The first shipment of ore, 40 tons, was transported out by rail in July 1870 (UDEQ - DERR, 2002). As many as 10 mills operated along the banks of Silver Creek throughout the history of mining in Park City. Tailings from the mining operations were washed downstream and accumulated in over-bank deposits in the floodplain throughout the LSC Site. Irrigation diversions may have spread the tailings and/or impacted Silver Creek waters to areas outside the floodplain. The Big Four Mill located near the present Pivotal Promontory access road was the primary mill operating within LSC. The mill was erected to process the zinc-lead-silver tailings accumulated in the LSC flats (Williams, 1916). The Big Four was said to be the third largest mill in Utah in 1916, consisting of a two-month stockpile of 50,000 tons of ore and the capacity to process 1,800 tons of ore tailings per day (UDEQ - DERR, 2002). The mine operated from 1915 to 1918. The Big Four tailings field was reportedly 3.5 miles long by 400 to 1,200 feet wide and two inches to eight feet deep. Today, the tailings exist in mounds, berms, and hummocks. There are two Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) listed sites upstream of LSC, Richardson Flat and Empire Canyon.

The Utah Division of Water Quality (UDWQ) and USGS have monitored the site for over 13 years. Silver Creek is listed on Utah's 303(d) list as impaired with a high ranking due to elevated concentrations of zinc and cadmium. In 2004, UDWQ published a Total Maximum Daily Load (TMDL) report in which Silver Creek was listed as impaired by zinc and cadmium because both constituents exceeded the 4-day chronic aquatic-life standards (UDEQ – DWQ, 2004).

Soils metal concentrations are also a concern. Lead and arsenic are the risk drivers for soil contamination. The UDEQ completed an Innovative Assessment in 2002 on the LSC floodplain; based on elevated lead and arsenic concentrations, UDEQ recommended the LSC Site for CERCLIS listing.

The Silver Creek watershed is a joint EPA water and waste program site. The initial TMDL assessment included gross (watershed-scale) load allocations and provided a summary of best management practices (BMPs) to reduce loading. Estimates for non-locationally-specific source control measures were nearly 100 million dollars. However, it was not the intent of the TMDL report to provide sufficient level of detail necessary to justify the expense of specific source reduction and remediation efforts. This study will provide additional water quality and sediment data, analyses, and modeling to describe the nature and extent of mine waste and metals loading and transport pathways. The goal of the study is to expand upon previous watershed level analyses and TMDL work to review, assess, and provide a combination of management options that maximize the efficiency (pollution reduction and cost) of restoration efforts in the watershed.

The Silver Creek project is part of a larger effort by EPA Region 8 to promote cross-program coordination to better focus resources on protection and restoration. To support this effort, EPA Region 8 recently led the development of a cross-programmatic watershed manual, *Integrating Water and Waste Programs to Restore Watersheds*. The goal of the manual is to enhance coordination across EPA waste and water programs to streamline requirements, satisfy multiple objectives, tap into a variety of funding sources, and implement restoration activities more efficiently, showing measurable results. The manual provides guidance on how to integrate assessment and cleanup activities to optimize available tools and resources and help restore contaminated waters efficiently and effectively.

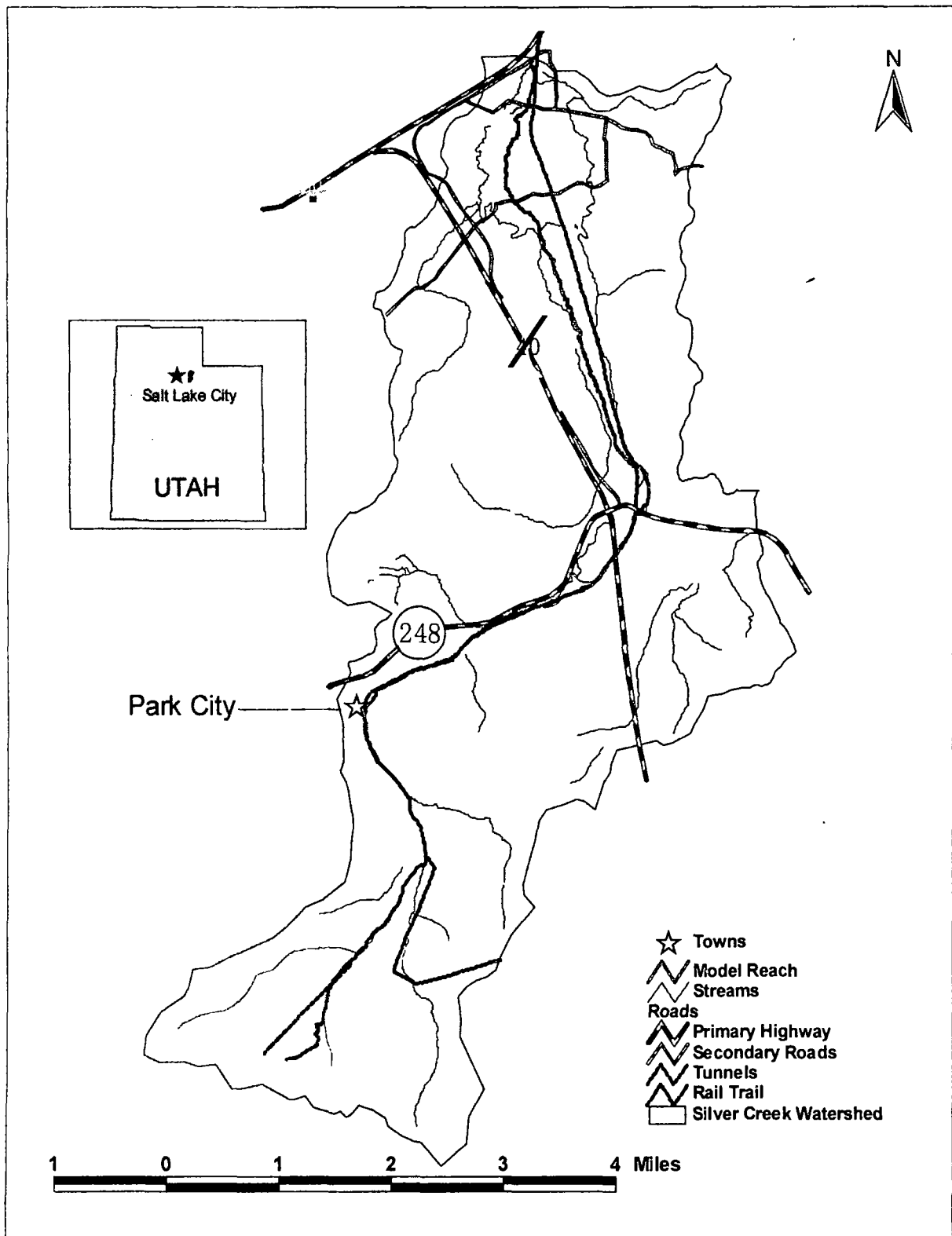


Figure 1-2: Project Location Map

1.3 Contaminant Generation and Pathways

Sources of contamination, such as abandoned mine shafts and adits as well as legacy overburden and tailings exist mainly in the Upper Silver Creek watershed. The major sources identified in past reports are: Empire Canyon, Anchor Tunnel, Ontario Tunnel, Prospector Square, Silver Maple Claims, Floodplain Tailings, Richardson Flat, and approximately 4 miles of deposited floodplain tailings between Highway 248 and Interstate 80. The Anchor and Ontario Tunnels both appear and are labeled on the USGS Topographic map near the confluence where Empire Canyon flows into Ontario Canyon. Clarification with the Park City Water Department will determine if these two tunnels are the same as the Spiro and Judge Tunnels, which are used as municipal drinking water sources.

Erosion and weathering of the Keetley Volcanic hills in the headwaters formed the valley's original soil surface (EPA, 2005). Mine tailings generally cover the entire riparian habitat on the southern portion of LSC from Highway 248 to near the Snyderville Water Reclamation Facility. The lateral extent and thickness of the tailings deposits are largely unknown. Tailings are visually apparent in the non-vegetated, gray colored sandy and/or gravelly mounds and low berms within the riparian habitat along LSC (UDEQ – DWQ, 2004). Elongated berms are found throughout the entire southern portion of the LSC Site and are oriented north-south. In some areas, soil cover is thin or absent, and tailings are exposed to the surface (EPA, 2005).

Vegetation in the southern portion of the wetland area around Richardson Flat is dominated by grass and sedge species and one tree. The sedge species grows in the drier areas surrounding the non-vegetated mounds and berms. This hardy sedge is reportedly not palatable to the livestock and grows 1 to 2 feet high. The livestock prefer the grass species found in the wetter areas (drainages and flood irrigated hummocks) and on the uplands. Several trees and a frog species were introduced to the area near Promontory Road as part of a wetlands mitigation project and neither the trees nor the frogs survived. The failed introduction of these species was apparently due to poor soil conditions reportedly resulting from metals toxicity. The northern portion of the project area is generally well-vegetated (UDEQ – DWQ, 2002).

The chemicals of concern (COCs) within the project area are zinc, cadmium, lead, and arsenic. The media affected by these contaminants are surface water, groundwater, sediment, and soils. Contamination in these media could potentially affect ecological receptors (zinc, cadmium, and lead) and humans (lead and arsenic). TMDL reductions are required for surface water cadmium and zinc. The COCs in sediment and soil are lead and arsenic. Soil disturbance caused by natural events, development or direct contact could result in exposure to COCs by ingestion, dermal exposure, and/or inhalation.

Metals in Silver Creek originate from sulfide mineral bearing ore deposits in the Park City Mining District. Some ores stem from skarn deposits hosted in carbonate rocks. Carbonate minerals also occur in intrusions as gangue minerals. Tailings from these ores should thus be abundant in sulfide and carbonate minerals (Utah Geological Society, 1968) and (USGS, 1989). The upper portions of the watershed contain numerous abandoned mines that may be contributing acid mine drainage (AMD) directly to the stream. The Prospector Square area is known to be built on tailings material that contributes contaminated water directly to Silver Creek.

Surface and groundwater are likely the predominate methods of transport for metals in Silver Creek. The typical mechanism for metals release in mining-affected streams is metal liberation resulting from exposure to acidic conditions. Acid is generated through oxidation of sulfide minerals, typically pyrite, which initially requires both oxygen and water to proceed. The oxidation reaction may be catalyzed by bacteria, as in the case of pyrite oxidation by the iron-oxidizing bacterium *thiobacillus ferrooxidans*. The products of pyrite oxidation are iron ions, sulfate, and hydrogen ions (low pH). The formation of sulfuric acid enhances mineral weathering, which, in turn, promotes metal availability. Many metals (aluminum, cadmium, copper, iron, manganese and zinc included) are more mobile in low pH (acidic) water. In the absence of sufficient buffering capacity, the formation of sulfuric acid leads to the generation of AMD. LSC generally has a neutral pH ranging from 7.5 to 8.0 indicating that low levels of pyrite are present in the tailings and/or it is well buffered by the presence of carbonate minerals present in the tailings.

In 2002, USGS performed a tracer study in LSC which showed that inflows to LSC had lower pH and higher metals concentrations than those in the mainstem. As inflows enter LSC and pH increases due to mixing with the mainstem waters, metals likely precipitate and settle into the stream sediment or move downstream in the particulate (e.g., sediment) form.

The practice of flood irrigation may be mobilizing metals from soils and tailings piles and serving as a metals transport pathway to LSC. Groundwater inflow to LSC is expected to be significant. Contaminants may be introduced to the LSC through the groundwater system. The extent of groundwater and surface water interaction in LSC is poorly understood as extensive studies have not been performed. Tetra Tech intends to sample significant inflows from tributary streams throughout the project area to determine the concentrations of COC and model these parameters in the chemical speciation model.

1.4 Project Description

This FSP covers work for the field effort to be performed during the high flow spring melt condition anticipated during April or May, 2008. This program encompasses work to collect and analyze surface water and sediment samples as well as obtain stream geometry and surface water flow measurements at each proposed sampling station. Each sampling station's coordinates will be captured using a sub-meter accuracy GPS unit.

2.0 PROJECT OBJECTIVES AND MEASUREMENT PERFORMANCE

Data quality objectives (DQOs) are qualitative and quantitative statements that clarify the intended use of the data, define the type of data needed to support the decision, identify the conditions under which the data should be collected, and specify tolerable limits on the probability of making a decision error due to uncertainty in the data (if applicable). DQOs are developed by data users to specify the data quality needed to support specific decisions.

2.1 Data Quality Objectives

The quality of an environmental monitoring program can be evaluated in three steps: (1) establishing scientific assessment quality objectives, (2) evaluating program design for whether the objectives can be met, and (3) establishing assessment and measurement quality objectives that can be used to evaluate the appropriateness of the methods being used in the program. The quality of a particular dataset is some measure of the types and amount of error associated with the data.

Sources of error or uncertainty in statistical inference are commonly grouped into two categories:

1. Sampling error: The difference between sample values and *in situ* “true” values from unknown biases due to sampling design. Sampling error includes natural variability (spatial heterogeneity and temporal variability in population abundance and distribution) not specifically accounted for in a design (for design-based inference), and variability associated with model parameters or incorrect model specification (for model-based inference).
2. Measurement error: The difference between sample values and *in situ* “true” values associated with the measurement process. Measurement error includes bias and imprecision associated with sampling methodology, specifications of the sampling unit, sample handling, storage, preservation, identification, instrumentation, etc.

The data requirements for this project encompass aspects of both laboratory analysis and some basic database management to reduce sources of errors and uncertainty in the use of the data.

The data requirements for this project encompass aspects of both laboratory analysis and database management to reduce sources of errors and uncertainty in the use of the data. Data needed for the project are listed in Table 2-1.

Table 2-1: Environmental Data to be Collected in the Silver Creek Watershed

Data Type	Measurement Endpoint/Detection Limit
<i>Physicochemical Parameters</i>	
Flow	gallons per minute [gpm], or cubic feet per second [cfs]
Temperature	degrees Centigrade [°C]
Conductivity	millisiemens per centimeter [mS/cm]
pH	range from 0 to 14
<i>Chemical Parameters</i>	
Wet chemistry	milligrams per liter [mg/L] or milligrams per kilogram [mg/kg]
Metals	micrograms per liter [µg/L] or milligrams per kilogram [mg/kg]
<i>Physical Sampling</i>	
Stream Channel Morphology	Stream width, bank height, in meters

Flow measurements are critical in stream assessments and TMDL modeling as they are essential to most pollution control activities. Flow measurements will be recorded at every sampling location to provide a comprehensive assessment of Silver Creek.

Electrolytic conductivity will be monitored at every sampling station throughout Silver Creek, as measurements are good indicators of dissolved mineral content in the stream ecosystems. Dissolved minerals and mineral salts can limit the beneficial use options for an impacted stream or watershed.

Another field parameter to be monitored is **pH**, which is a measure of the acidity (hydrogen/hydroxide ion concentration) of waterbodies identified for characterization and assessment. Most aquatic organisms have a preferred range of pH, usually pH 6 to 9. Beyond that range aquatic organisms begin to suffer stress, which can lead to death. High pH concentrations also force dissolved ammonia into its toxic, un-ionized form, which can further stress fish and other organisms. It is important to monitor effluent pH to ensure that wastewater discharges do not alter the pH of receiving water or affect the efficiency of biological or physiochemical treatment processes.

Temperature will be measured in the field at all collection sites, because temperature can indicate flow conditions and can be useful in the overall watershed characterization. While fluctuation and variability in temperature have only moderate effect in other than extreme change, on the health of a watershed under anything other than extreme conditions.

Some of the wet chemistry parameters consist of **DOC**, which identifies the quantity of material in the stream that is likely to consume oxygen as it breaks down in receiving streams. Oxygen depletion can kill fish and benthic invertebrates in streams and rivers. DOC is an important modeling variable to describe current condition and biochemical processes taking place in the watershed.

Some of the other wet chemistry parameters consist of **total suspended solids (TSS)** which may adversely effect stream ecosystems through undesirable deposition and siltation, and through physical toxic effects ("gill breaking"). Because some metals and nutrients bind to solids, and available pH profile data from the Upper Silver Creek and the Lower Silver Creek suggest that some metals may precipitate out of contributing source waters in the upper watershed and are transported through the lower watershed or are deposited in the sediments of the Lower Silver Creek. TSS is an important variable in the interpretation of loading conditions, especially during the spring snow melt sampling.

Metals are being monitored because they are the listing impairment in the lower watershed and in the soils in the surrounding floodplain. They remain important indicators of mine runoff sources and will a primary focus in the management alternatives explored through the modeling effort. Metals can be toxic to algae, benthic, and aquatic species. Although metals may serve useful purposes within an ecosystem, most metals retain their toxicity within an aquatic ecosystem.

This study is being undertaken to provide information that will be used to determine the best *remediation alternatives for the study area*. Pollutant loadings may require management to reduce

risks to the health of humans and organisms dependent on the quality of the water. Loss of in-stream fish and invertebrate populations, for example, can occur if chemical contaminants exceed certain thresholds or risk-based criteria. Uncertainty in the data due to sampling and measurement errors or errors introduced during data manipulation could result in identifying the potential for an effect on the population when one does not exist or in not identifying an effect when one does exist. Reducing data uncertainty is of highest priority. These data will not be used to promulgate regulations, although it is still important to reduce uncertainty using appropriate QC protocols. Discussion of conventional data quality indicators, i.e., precision, accuracy, completeness, representativeness, and comparability, follows this section.

Methods and procedures described in this document are intended to reduce the magnitude of measurement error sources and frequency of occurrence. The relevant quality objectives for this project are related to sample handling, as well as making measurements of certain parameters onsite. Project quality objectives include the following:

- Use of standardized, repeatable data and sample collection procedures.
- Use of trained scientists to perform the data and sample collection and analyses.
- Calibration of meters for flow rate, pH, temperature, conductivity, or other parameters to be collected on site to a known standard as per manufacturer's specifications.

2.2 Measurement Performance Criteria

Measurement performance criteria are quantitative statistics used to interpret the degree of acceptability or utility of the data to the user. These criteria, also known as data quality indicators (DQIs), include the following:

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability

Following data entry operations, all spreadsheets will be proofread using the original handwritten field log notebook. This review will be done by someone other than the data entry specialist.

Measurement performance criteria for data to be collected during this project are discussed in the following sections.

Precision

Precision is a measure of internal method consistency. It is demonstrated by the degree of mutual agreement between individual measurements or enumerated values of the same property of a sample, usually under demonstrated similar conditions. Precision of sampling methods is estimated by taking duplicate samples at the same sampling site at approximately 10 percent of the sites. In

addition, analytical precision is estimated through analysis of laboratory duplicates or of spiked duplicates (matrix spike and matrix spike duplicate; MS/MSD).

This QC calculation also addresses uncertainty due to natural variation and sampling error. Precision is calculated from two duplicate samples by relative percent difference (RPD) as follows:

$$RPD = \frac{|C_1 - C_2|}{(C_1 + C_2) / 2} \times 100 \%$$

where C_1 = the larger of the two values and C_2 = the smaller of the two values. If it is to be calculated from three or more replicate samples (as is often the case of laboratory analytical work), the relative standard deviation (RSD) will be used and is calculated as

$$RSD = \frac{s}{\bar{X}}$$

where s = standard deviation and \bar{X} = mean of repeated samples. The standard deviation or the standard error of a sample mean(s) is calculated as:

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n-1}}$$

where X_i = measured value of the replicate, \bar{X} = mean of repeated sample measurements, and n = number of replicates. Precision can also be expressed in terms of the range of measurement values.

For this project, duplicate field samples to assess pollutants in wastewater or other media will be collected. Physicochemical measurements of the wastewater stream at each sampling point will also be collected and the precision of their measurements will be determined.

Accuracy

Accuracy is defined as the degree of agreement between an observed value and an accepted reference or true value. Accuracy is a combination of random error (precision) and systematic error (bias), which are due to sampling and analytical operations. Bias is the systematic distortion of a measurement process that causes errors in one direction so that the expected sample measurement is always greater or lesser to the same degree than the sample's true value. EPA now recommends that the term *accuracy* not be used and that *precision* and *bias* be used instead (USEPA, 1995).

Since accuracy is the measurement of a parameter and comparison to a "truth," and the true values of environmental physicochemical characteristics cannot be known, use of a surrogate is required. Accuracy of field measurements will be assumed to be determined through use of precision. Accuracy of laboratory chemical measurements will be determined by analysis of laboratory control samples (LCS; fortified blanks); certified standard reference materials (SRMs), where available and appropriate; MS/MSD samples and other method-specified QC samples. Fortified blanks are the

most common bias assessment tool, as they are prepared from readily available materials and laboratory water or other artificial matrices. If third-party SRMs are available used, recoveries for target analytes should fall within the manufacturer's certified range. In the absence of manufacturers certified range, recoveries for spiked analytes should not exceed $\pm 20\%$ of the true values to be acceptable (unbiased).

Recoveries for spiked control samples and certified SRMs are calculated as follows:

$$\% \text{ Recovery} = \frac{\text{analytical result}}{\text{true value}} \times 100\%$$

Certified ranges for SRMs are often provided as a range of total concentrations in $\mu\text{g/L}$ or mg/L . In such cases, evaluation of their acceptability is achieved through direct comparison to the manufacturer's certified range.

MS and MSD samples are spiked aliquots of a field sample. Recoveries for MS/MSD samples are calculated individually and must account for sample-native (background sample) concentrations of the spiked target analyte. As such, their recoveries are calculated as follows:

$$\% \text{ Recovery} = \frac{(\text{spiked sampler result} - \text{sampler result})}{\text{amount spiked}} \times 100\%$$

Where the *sampler result* is the concentration measured in the unspiked sample and the *spiked sampler result* is the concentration measured in the MS or MSD spiked aliquot.

The accuracy of field equipment for the measurement of temperature, turbidity, dissolved oxygen, conductivity, salinity, and pH will be determined at a minimum of two points which span the expected range of values for these parameters.

Representativeness

Data representativeness is defined as the degree to which data accurately and precisely represent a characteristic of a population, parameter, variations at a sampling point, a process condition, or an environmental condition. It therefore addresses the natural variability or the spatial and temporal heterogeneity of a population.

Completeness

Completeness is defined as the percentage of measurements made that are judged to be valid according to specific criteria and entered into the data management system. To achieve this objective, every effort is made to avoid accidental or inadvertent sample and/or data loss. Accidents during sample transport or lab activities that cause the loss of the original samples will result in irreparable loss of data. Lack of data entry into the database will reduce the ability to perform analyses, integrate results, and prepare reports. Samples will be stored and transported in unbreakable (plastic) containers. All sample processing will occur in a controlled environment

within the laboratory. Field personnel will assign a set of continuous identifiers to a batch of samples.

Percent completeness (%C) for measurement parameters can be defined as follows:

$$\%C = \frac{V}{T} \times 100$$

where V = the number of measurements judged valid and T = the total number of measurements. For this project, sampling will be considered complete when no less than 90% of the measurements collected during a particular sampling event are judged valid.

Comparability

Two data sets are considered to be comparable when there is confidence that the two sets can be considered equivalent with respect to the measurement of a specific variable or group of variables. Comparability is dependent on the proper design of the sampling program and on adherence to accepted sampling techniques, standard operating procedures, and quality assurance guidelines. For sampling at the Silver Creek Watershed sampling locations, comparability of data is ensured by similarity in sampling methods, parameter measurement protocols, and use of analytical chemistry methods as determined by EPA, as well as by uniform training and experience of field sampling and laboratory personnel.

DQIs that cannot be expressed in terms of accuracy, precision, or completeness will be reported by fully describing the specified method; all other quality requirements will be fulfilled. In accordance with the specifications of the referenced analytical methods (Section 7.0), laboratory acceptance windows and criteria should be based on in-house statistical data developed through actual spiked sample analyses.

Table 2-2 shows the accuracy, precision, and completeness requirements for the Silver Creek Watershed water quality data.

Table 2-2: Measurement Performance Criteria

Data Type	Water		Completeness
	Accuracy	Precision	
<u>Field Measurements</u>	<u>%RPD</u>	<u>%Recovery</u>	≥90
Stream flow			
Temperature	0.2 °C ¹	±20%	
Conductivity	± 0.001 to ± 0.1 mS/cm ¹	±20%	
pH	± 0.01 units ¹	±20%	
<u>Metals (CLP)</u>	<u>%RPD</u>	<u>% Recovery</u>	≥90

Aluminum, Arsenic, Barium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Silver, Zinc	20	±20%	
<u>Additional Parameters</u>			≥90
Total Suspended Solids (TSS)	20% RPD	±20%	
Sulfate	20% RPD	±20%	
Ferrous (Fe ²⁺) Iron	20% RPD	±20%	
Ferric (Fe ³⁺) Iron (calculated)	20% RPD	±20%	
Dissolved Organic Carbon (DOC)	20% RPD	±20%	

NA = Not available

¹ Dependent upon range of measurement used on field instrumentation.

In accordance with the specifications in most of the referenced analytical methods, laboratory acceptance windows and criteria should be based on in-house statistical data developed through actual spiked sample analyses. The criteria stated in Table 3 are the minimum performance criteria established in the prescribed methods, respectively. These values are minimum acceptance criteria for laboratory control samples, and fortified blanks, as specified in the reference methods, or more arbitrary limits routinely employed in common laboratory practices. Analyses of Standard Reference Materials (SRMs), where available and appropriate, should be evaluated against the certified range(s) as provided by the manufacturer, or certifying agency. Reference methods may provide additional criteria for surrogate recovery and target analyte recoveries in spiked field samples.

3.0 SAMPLING LOCATION AND FREQUENCY

This section presents a description of the location and frequency of field activities. Field methods, sampling procedures, and QA/QC protocols are presented.

3.1 Groundwater Sampling

Groundwater sampling will be performed at the closest piezometer to the stream at each of the six transect locations established during Phase I and Phase II field work.

3.1.1 Sampling Locations

Two to four one-inch diameter piezometers were installed on each transect by the Geoprobe subcontractor during Phase I and Phase II field activities. Each piezometer was constructed of 3/4-inch ID PVC with three or five-foot screen lengths and 0.010-inch slots. The piezometers include a factory installed sand pack around the well screen. Piezometers were generally located within the floodplain area. Four inch diameter PVC pipe casing was driven into the ground bracketing the piezometers to deter livestock from damaging the piezometers; PVD caps were placed on the piezometers and the casings. Table 3-1 contains the piezometer identification, location description, and analytical parameters. Figure 3-1 shows the locations of the piezometers.

Table 3-1: Groundwater Piezometers to be Samples

Piezometer ID	Location Description	Total Metals¹	Dissolved Metals¹ (field filtered with 0.45 micron)	Additional Analytical Parameters²
P2-5	North of the sewage treatment plant road, at the USGS Gage	X	X	X
GW6E0375	Transect -6	X	X	X
GW5E1875	Transect -5	X	X	X
P2-4	Transect -4	X	X	X
GW3E0625	Transect -3	X	X	X
GW2E0125	Transect -2	X	X	X
GW1E0125	Transect -1	X	X	X

¹ Metals analytical suite includes: Aluminum, Arsenic, Barium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Silver, and Zinc

² Additional analytical suite includes: Ferrous (Iron⁺²), Ferric (Iron⁺³), Sulfate, and Dissolved Organic Carbon

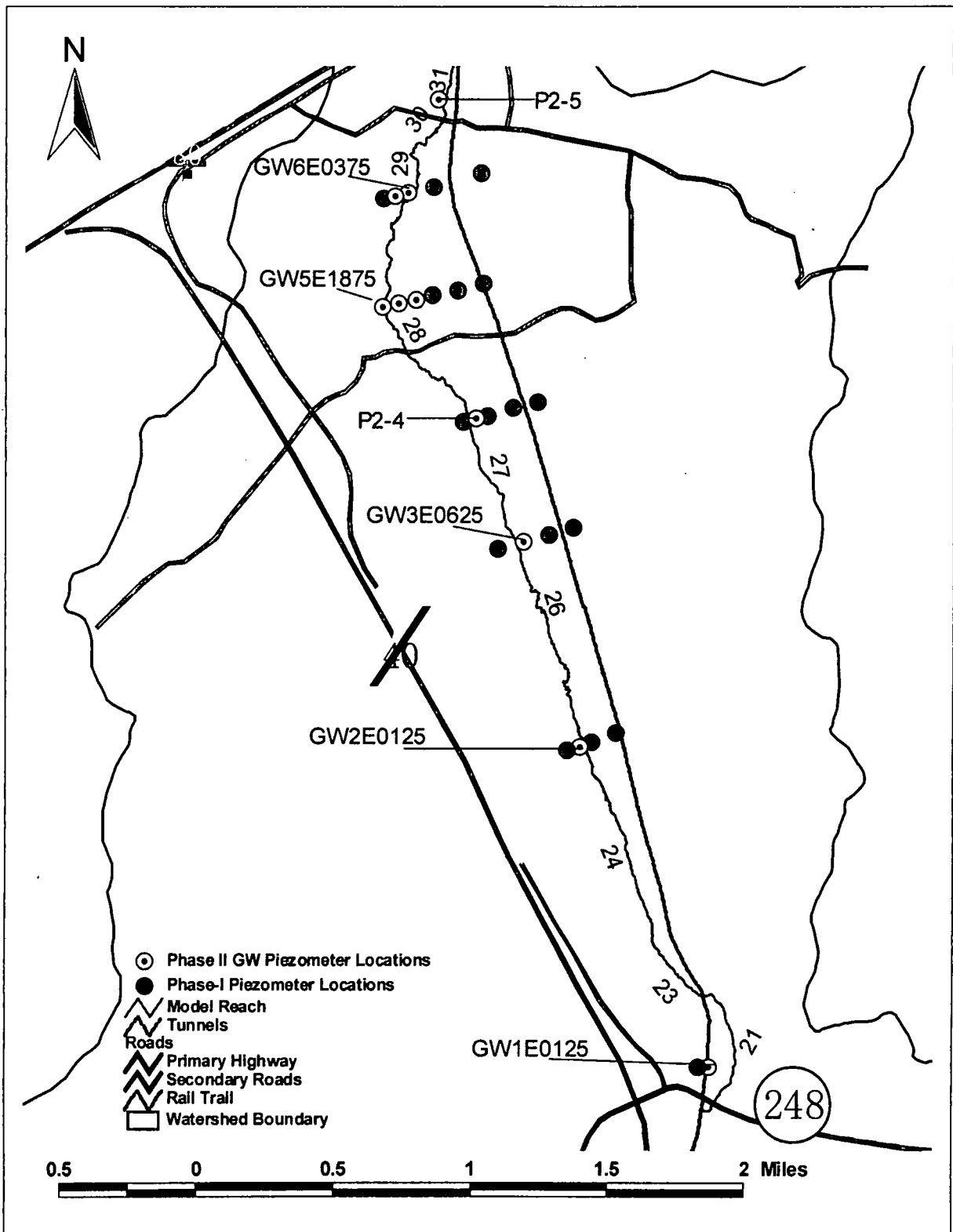


Figure 3-1: Groundwater Piezometer Locations to be Sampled

3.1.2 Sampling Frequency

Groundwater sampling will be conducted during the spring sampling event scheduled for May 31 to June 6, 2008. Water levels will be measured in the piezometers closest to the stream and filtered and unfiltered groundwater samples will be collected. Samples will be analyzed for total and dissolved metals (aluminum, cadmium, iron, manganese, and zinc), calcium, magnesium, and sulfate. Groundwater samples will also be analyzed for iron speciation between the ferrous and ferric states. The groundwater analysis will help establish a knowledge base for evaluating contaminant transport and distribution through the groundwater/surface water interface.

3.2 Surface Water and Sediment Sampling

Optimal surface water sampling locations were identified during the Phase I and Phase II field activities. Additional locations were identified during the preliminary model setup and seamless conceptual model configuration for upper and lower Silver Creek. Surface water and sediment samples will be collected during the spring 2008 fieldwork. At this time, it is anticipated that 43 sample locations will be sampled during the spring 2008 sampling event to support the modeling, provided field conditions allow samples to be collected. Sampling locations are placed at optimal locations for modeling purposes, such as: bracketing contaminant sources, upstream, downstream, and within each diversion or braid of the main Silver Creek channel. Samples will be configured similarly where tributary streams enter the main stem of Silver Creek. Additional discretionary sample locations will be positioned along the stream in areas observed to bracket unknown sources or inflows to Silver Creek. Samples will be collected from downstream to upstream order.

It is anticipated that the volume of water present in Silver Creek will allow for single point grab surface water samples. These samples will be collected in accordance with EPA ERT Standard Operating Procedure (SOP) No. 2013 – *Surface Water Sampling* (Appendix A), modified as follows. Single point grab samples may be collected from streams of very small width, or from larger streams or rivers when access to the stream or river poses a safety concern (i.e., during high flow).

All water samples will be collected using a GeoTech Geo Pump Series II peristaltic pump outfitted with an EZ-load II pump head with new or dedicated sample tubing. All tubing will be discarded after a single sampling station (single use) to avoid cross contamination. The plastic or silicon tubing will be immersed directly into the water body being sampled, and allowed to pump for 3-4 minutes to surface water for stream sampling or to ground for groundwater sampling prior to collection of sample aliquots for analysis to effect rinsing of the tubing with site water.. Depending on the proximity of the sample locations, samples may be returned to a staging area where the 0.45 micron filtering and sample preservation with nitric acid will take place. If this is not possible, the sample will be filtered and preserved at the sample location. The sample containers will then be labeled and packaged for shipment to the analytical laboratory. The information provided on container labels will include: time and date the sample was collected; sampling location; preservative used; initials of person who collected the sample; and a sample code (e.g., SC-SW-1). Finally, all sampling activities will be recorded in the field notebook and all sample locations will be surveyed with GPS equipment and photographed with a digital camera.

Surface water samples will be tested in the field for pH using an Orion 250A or Orion 261 pH meter and specific conductance measurements will be taken with a Cole-Palmer 1481-61 or Cole-Palmer CON 400 meter or similar instrumentation. Field instruments will be calibrated prior to sampling each day during the field activities. Stream flow and channel dimensions will be taken at all designated sample locations. Surface water samples will be analyzed by an EPA contract laboratory for total and dissolved metals including: aluminum, cadmium, calcium, iron, magnesium, manganese, and zinc. Sulfate and total suspended solids will also be analyzed.

Sediment samples will be co-located at the surface water sample locations to evaluate the concentration of total metals. The samples will be collected with a decontaminated stainless steel scoop or disposable plastic scoop and placed in the appropriate sample container, typically a four ounce glass jar. The sample containers will then be labeled and packaged for shipment to the analytical laboratory. The information provided on container labels will include: time and date the sample was collected; sampling location (which will correspond with the surface water sample); initials of person who collected the sample; and a sample code (SC-SED-1). All sampling activities will be recorded in the field notebook, surveyed with GPS equipment and photographed with a digital camera.

Sediment samples will be analyzed by an EPA CLP laboratory for total and dissolved metals suite including: aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron lead, magnesium, manganese, silver, and zinc. The sediment samples will first be extracted using the EPA SW846 Method 1312 synthetic precipitation leaching procedure (SPLP), and then analyzed by EPA SW846 Method 6020A inductively-coupled plasma mass spectroscopy (ICP-MS) as described in Section 7.0.

Table 3-2 shows the anticipated sample stations and the parameters to be collected during the field sampling. The location of the sampling stations is presented in Figures 3-2 to 3-5. This data will be used during the chemical speciation transport modeling of the high flow condition in Silver Creek.

Table 3-2: Proposed Sample Locations

Sample ID	Model Segment	Station Description	Flow	Total and Dissolved Metals Analysis¹	Additional Analysis²	Sediment SPLP Analysis
SC-SW-1	34	Silver Creek Below the Secondary Drainage from Sewage Treatment Plant (STP)	X	X	X	
SC-SW-2	34	Secondary Drainage Inflow from (STP)	X	X	X	
SC-SW-3	33	Silver Creek Above the Secondary Drainage from (STP)	X	X	X	X
SC-SW-4	32	Silver Creek Below Irrigation Ditch Return Near Dairy Farm	X	X	X	X
SC-SW-5	31	Inflow from Irrigation Ditch Near Dairy Farm	X	X	X	

Sample ID	Model Segment	Station Description	Flow	Total and Dissolved Metals Analysis¹	Additional Analysis²	Sediment SPLP Analysis
SC-SW-6	30	Silver Creek below Sewage Treatment Plant at the USGS Gage Station	X	X	X	X
SC-SW-7	29	Discharge from (STP)	X	X	X	
SC-SW-8	29	Silver Creek Above the (STP)	X	X	X	
SC-SW-9	28	Silver Creek downstream of unnamed Tailings 3 (Big Four Mill Area)	X	X	X	X
SC-SW-10	27	Silver Creek downstream of Lower Middle Tailing 2 (Lower Meadow Tailing)	X	X	X	X
SC-SW-11	27	Inflow from UNT to Lower Silver Creek	X	X	X	
SC-SW-12	26	Silver Creek Below Transect 3	X	X	X	X
SC-SW-13	25	Silver Creek below the confluence with UNT	X	X	X	
SC-SW-14	24	Inflow from UNT to Silver Creek	X			
SC-SW-15	23	Silver Creek downstream of unnamed Tailing 1 (Upper Meadow Tailing)	X	X	X	X
SC-SW-16	22	Silver Creek at the Rail Trail trestle near the cement plant	X	X	X	X
SC-SW-17	21	Silver Creek downstream of the UNT (Diversion Channel & Silver Creek are same)	X	X	X	X
SC-SW-18	21	UNT of the diversion channel (Diversion Channel & Silver Creek are same)	X	X	X	
SC-SW-19	20	Silver Creek below diversion of the irrigation ditch	X	X	X	X
SC-SW-20	31	Irrigation diversion above Homer Pace Ditch (if it exists)	X			
SC-SW-21	31	At the Mouth of the irrigation diversion ditch (if it exists)	X			
SC-SW-22	19	Silver Creek Below Richardson Flat Tailings at Rail Trail trestle	X	X	X	X
SC-SW-23	18	Inflow from drainage ditch along US-40 (if it exists)	X			
SC-SW-24	18	Silver Creek Below Floodplain Tailings above Richardson Flat Tailings	X	X	X	X
SC-SW-25	17	Diversion from Dority Springs to Silver Creek (if it exists)	X			
SC-SW-26	16	Silver Creek Above Floodplain Tailings	X	X	X	X

Sample ID	Model Segment	Station Description	Flow	Total and Dissolved Metals Analysis ¹	Additional Analysis ²	Sediment SPLP Analysis
SC-SW-27	31	Diversion to the irrigation ditch (if it exists)	X			
SC-SW-28	15	Downstream of Silver Maple Claims	X	X	X	X
SC-SW-29	14	Silver Creek Above Silver Maple Claims	X	X	X	X
SC-SW-30	13	Inflow to Silver Creek from Dority Springs	X			
SC-SW-31	12	Silver Creek upstream of confluence with Dority Springs	X	X	X	X
SC-SW-32	11	Silver Creek Below Prospector Square	X	X	X	X
SC-SW-33	10	Silver Creek Above Prospector Square	X	X	X	X
SC-SW-34	9	Silver Creek downstream of the confluence of Ontario Canyon and Silver Creek (if it exists)	X	X	X	X
SC-SW-35	8	Silver Creek Above the confluence of Ontario Canyon (if it exists)	X	X	X	
SC-SW-36	7	Ontario Canyon Above the confluence of Silver Creek (if it exists)	X	X	X	X
SC-SW-37	6	Ontario Canyon Below the Confluence Ontario Canyon and Ontario Drain Tunnel No 2	X	X	X	X
SC-SW-38	6	At the mouth of Ontario Drain Tunnel No 2	X	X	X	
SC-SW-39	5	Ontario Canyon Above the confluence of Empire Canyon and Ontario Drain Tunnel No 2	X	X	X	
SC-SW-40	4	At the mouth of Empire Canyon (if it exists)	X	X	X	X
SC-SW-41	3	Mouth of Walker & Webster Gulch (if it exists)	X	X	X	
SC-SW-42	2	Mouth of the Anchor Tunnel	X	X	X	
SC-SW-43	1	Upstream of Anchor Tunnel and Tailings (if it exists)	X	X	X	X

¹ Metals analytical suite includes: Aluminum, Arsenic, Barium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Silver, and Zinc

² Additional analytical suite includes: Ferrous (Iron⁺²), Ferric (Iron⁺³), Sulfate, and Dissolved Organic Carbon

3.2.1 Sampling Locations

Figures 3-2 through 3-5 show the known sources of contamination and the proposed sampling locations to be collected during the spring 2008 sampling event.

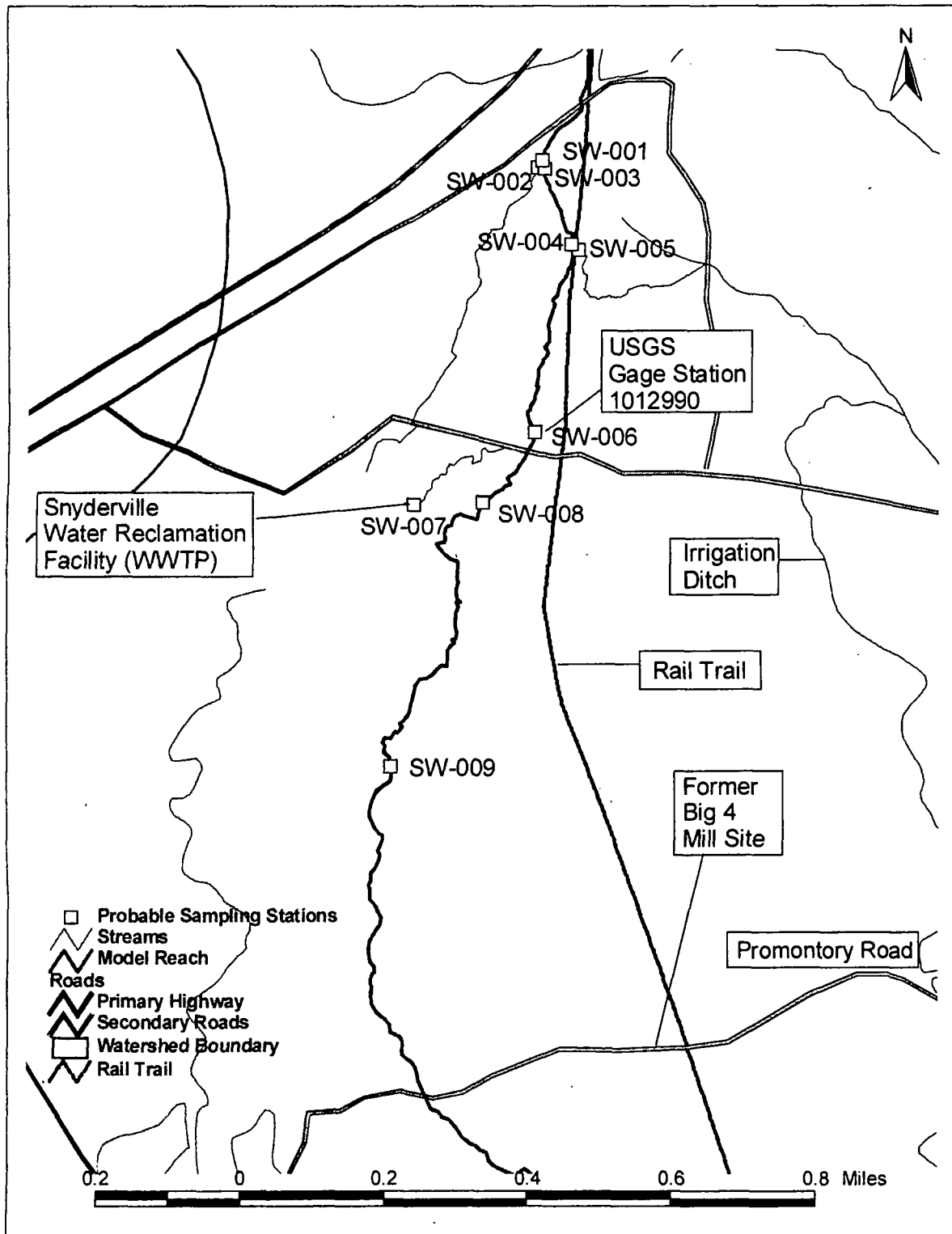


Figure 3-2: Sources and Proposed Sample Locations from Promontory Road to I-80

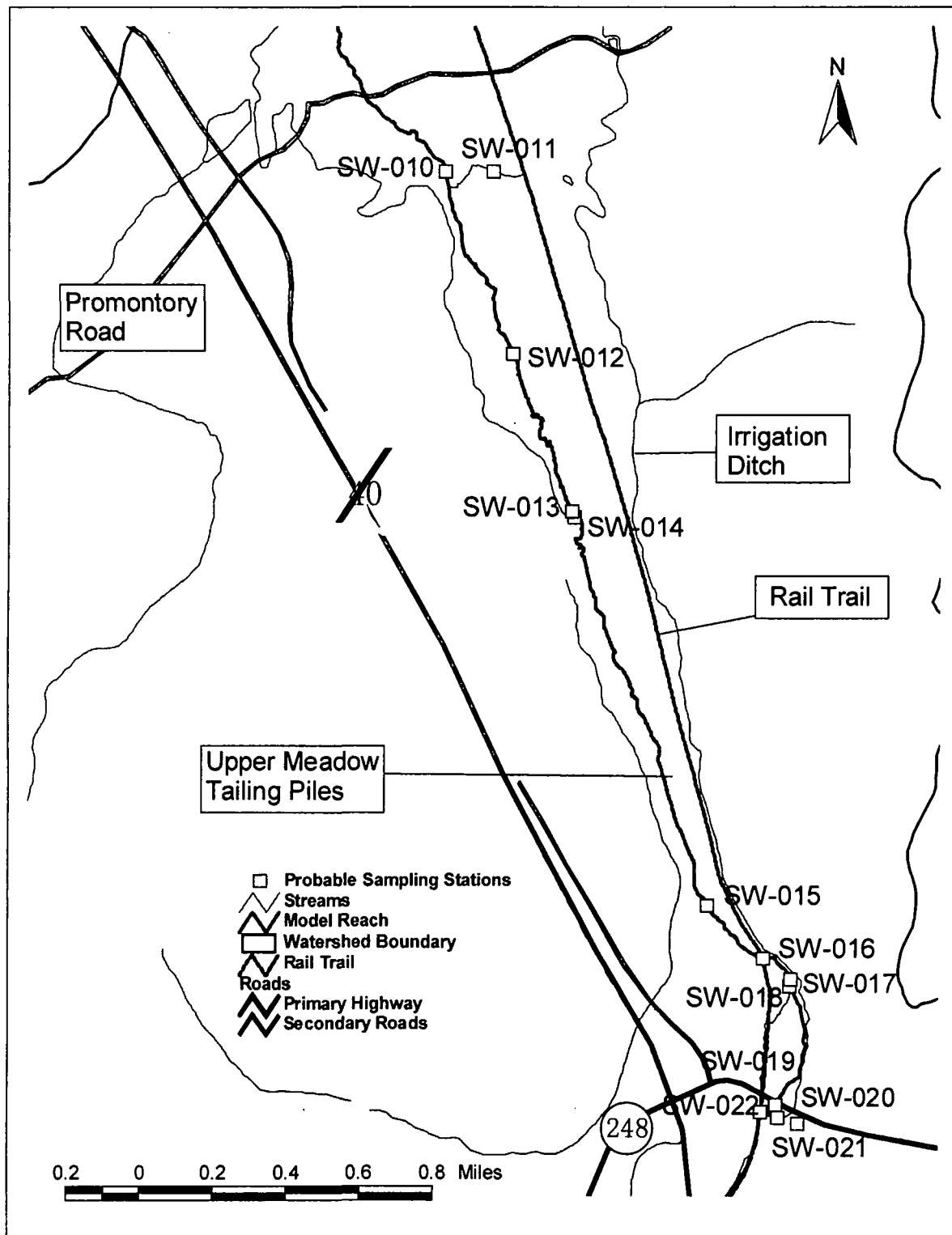


Figure 3-3: Sources and Proposed Sample Locations from Highway 240 to Promontory Road

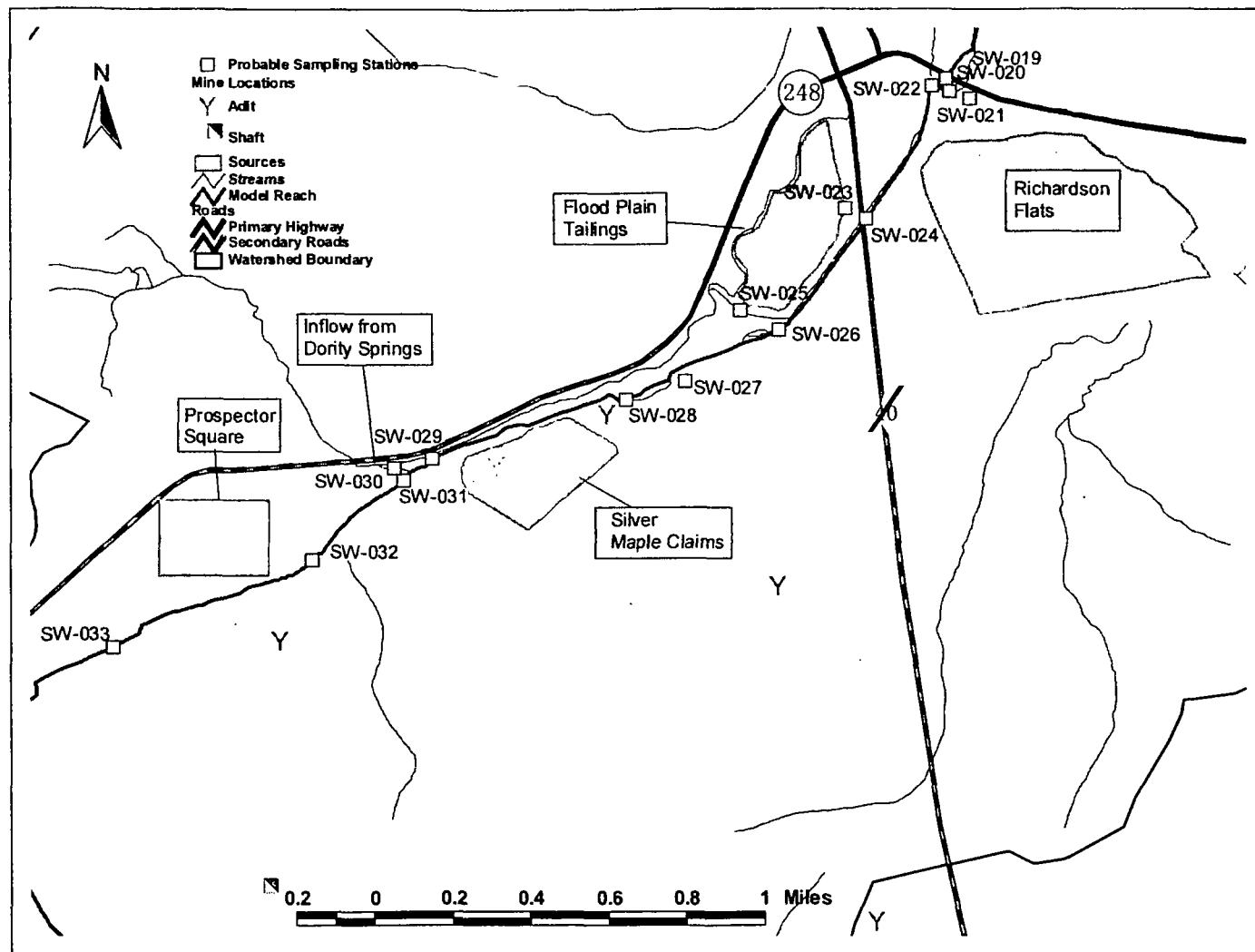


Figure 3-4: Sources and Proposed Sample Locations from Prospector Square to Highway 240

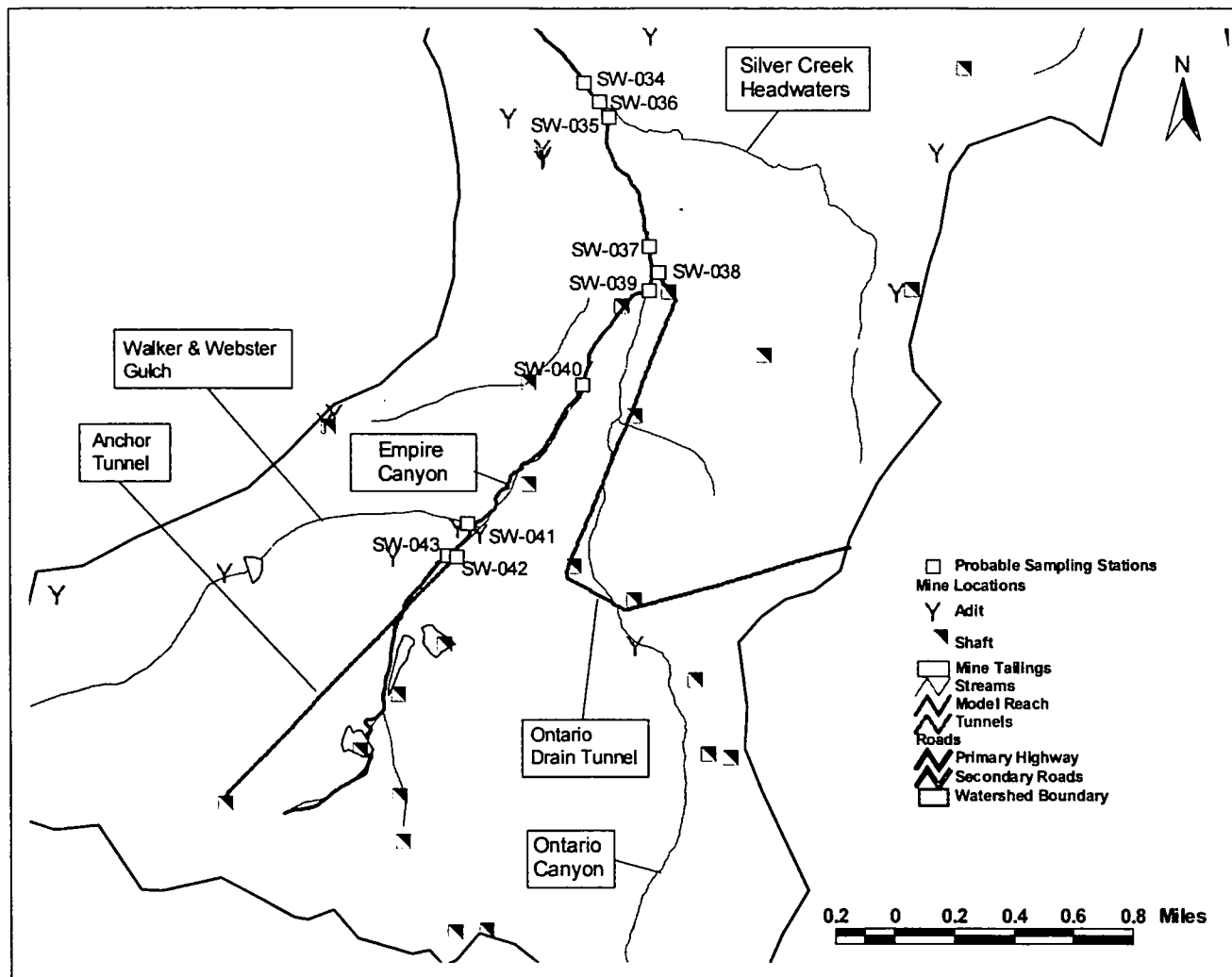


Figure 3-5: Sources and Proposed Sample Locations from Empire Canyon to Prospector Square

3.2.2 Sampling Frequency

Surface water and sediment samples will be one time grab samples at each location.

4.0 SAMPLE DESIGNATION

Water samples will be labeled using the project name, Silver Creek (SC), the type of sample (ie. groundwater [GW], surface water [SW], or sediment [SED]), and finally the predetermined location number. For example, a surface water and sediment sample would be identified as SC-SW-1 and SC-SED-1. A groundwater sample would be labeled according to which piezometer it was collected, for example SC-GW-(Piezometer ID)

Field duplicate samples will be designated with a "D" after the sample location. If necessary, equipment rinsate samples will be designated as "SC-SW-ERB or SC-SED-ERB". It is expected to use either dedicated sampling equipment or disposable equipment for all sample collection, therefore it is not anticipated that any equipment rinsate blanks will be collected. Sample aliquots collected for laboratory QA/QC analyses will be given the same identification as the primary sample and noted on the chain of custody as "extra bottles for QA/QC analyses".

5.0 SAMPLING EQUIPMENT AND PROCEDURES

Field instruments will be inspected and calibrated prior to deployment in the field. Pre-preserved sample kits will be picked up by the Sampling Team Leaders at the laboratory and inspected prior to use at the site.

At each sample collection location, the following information will be recorded in the field logbook or on a designated field form:

- Names of field personnel
- Date/time of measurement
- Measurement identification location (transect, station, etc.)
- GPS coordinates
- General weather conditions (e.g. hot, windy, no precipitation)
- Description and location of nearby features (e.g. shafts, building foundations, cribbing), if visually present
- Description and location of water drainage paths, if present near the measurement location
- General description of adjacent vegetation conditions
- Sample identification, sample collection location, and collection time, if sample is collected
- Any problems encountered or deviations in sample collection methods
- Description of any unusual circumstances
- Photo documentation details, if necessary

5.1 Groundwater Sampling

Each well will be developed by purging at least five well volumes with a peristaltic pump. Well development will follow EPA Region 8 protocols set forth in Appendix B SOP #3.2 – *Well Development*. The SOP for obtaining water levels is included in Appendix C, Tetra Tech SOP - *Water Level, Immiscible Layer, and Well Depth Measurement*. During the spring 2008 sampling, groundwater samples will be collected from select piezometers and analyzed for total and dissolved metals (aluminum, cadmium, iron, manganese, and zinc) calcium, magnesium, and sulfate. Water sampling procedures are described in more detail in the SOP included in Appendix D, EPA ERT SOP No. 2007 – *Groundwater Well Sampling*.

5.2 Surface Water and Sediment Sampling

Tetra Tech proposes to collect surface water and sediment samples in accordance with the criteria specified in the Appendix A, EPA ERT SOP No. 2013 – *Surface Water Sampling*, and Appendix E, USGS OFR 90-140 – *Methods for Collection and Processing of Surface-Water and Bed-Sediment Samples for Physical and Chemical Analyses*. Surface water samples will be collected from downstream to upstream. Depending on flow conditions, stream sediment samples may be collected on the day(s) following the surface water sampling. This practice may be followed to limit turbid water conditions, which can bias analytical results. Sufficient sample quantity (typically 2 liters) will be collected to satisfy the volume requirements for the surface water analyses selected. Flow measurements will be taken following the criteria stated in ASTM D3858-95 – *Open-Channel Flow Measurement of Water by Velocity-Area Method*.

Tetra Tech proposes to collect sediment samples in accordance with the criteria specified in Appendix E, USGS OFR 90-140 – *Methods for Collection and Processing of Surface-Water and Bed-Sediment Samples for Physical and Chemical Analyses*. Sufficient sample quantity (16 ounces) will be collected to satisfy the volume requirements for the analyses selected.

5.3 Sampling Equipment Decontamination

Decontamination procedures will be conducted in accordance with the guidance provided in the Appendix F, EPA *Standard Operating Procedure (SOP) No. 2006, Sampling Equipment Decontamination*. Reusable sampling equipment will be decontaminated between each sample collection utilizing the following procedure:

- Each item will be scrubbed with a brush using tap water and a low phosphate detergent;
- After gross decontamination, each item will be rinsed three times with distilled/deionized water;
- After the distilled/deionized water rinse, each item will be rinsed with a 10 percent nitric acid solution;

- After the item has dried it will be given a final rinse with distilled/deionized water;
- Decontamination fluids, if generated, will be returned to the ground based on guidance provided in the Appendix G, EPA Region VIII SOP #1.6.5 – *Handling of Investigation-Derived Waste*.

Decontamination procedures will be carefully conducted to ensure that contamination is neither introduced externally during the sampling process nor transferred by cross-contamination between sample locations. Cleaned equipment will be bagged between sampling stations to avoid environmental contamination. Personnel involved in sampling equipment preparation, sample collection, and processing will wear latex or nitrile gloves to protect themselves and to minimize the opportunity for sample contamination.

5.4 Investigation Derived Waste

Investigation derived wastes (IDW) generated during the course of the field activities (e.g., decontamination water, personal protective equipment (PPE), and disposable sampling equipment) is expected to be minimal. Nevertheless, the wastes will be treated as Resource Conservation and Recovery Act (RCRA) hazardous or non-hazardous materials, as appropriate, and managed according to the criteria established in the Appendix G, EPA Region VIII SOP #1.6.5 – *Handling of Investigation-Derived Waste*. It is expected that the IDW generated during site activities will be limited to decontamination water (both from hand tools and auger flights), latex gloves, and other PPE. PPE will be rinsed before disposal and sent to a municipal sanitary landfill. The decontamination water, if generated, will be returned to the ground so as not to migrate off site.

5.5 Surveying

Surveying of all surface water and soil sample locations will be performed by Tetra Tech personnel with hand held GPS units. Professional surveyors will be subcontracted to survey the piezometer installations. Survey for the wetlands delineation will be performed using a Trimble GeoXT sub-meter GPS unit.

6.0 SAMPLE HANDLING AND CUSTODY PROCEDURES

Each sample will be properly labeled in the field. Samples will be individually entered by sample number on the chain-of-custody form. After collection, individual samples will be placed in a cooler or other suitable container for storage in the field. Samples will be shipped to the laboratory in a cooler with ice. The ice in the cooler will be double-bagged. One copy of the chain-of-custody form will be enclosed in a plastic bag in each cooler containing the samples identified on the form. Chain-of-custody protocol will be maintained for samples from the time of collection until their final deposition. The cooler will be taped shut and custody seals will be attached to the outside of the cooler to ensure

that the cooler cannot be opened without breaking the seal. The cooler will be shipped using an authorized shipping service or hand delivered to the laboratory for analysis.

Duplicate or co-located samples (for groundwater and surface water) or split samples (for sediment) will be collected and submitted to the laboratory to ensure the precision and reproducibility of sample collection and processing procedures. Duplicate samples will be collected for approximately 10 percent of the total samples. It is anticipated that one duplicate will be collected from groundwater, three to four duplicates will be collected from surface water, and three to four split samples will be selected for collection, processing, and submittal of split samples for sediment, and three to four duplicates or co-located samples will be collected and submitted for surface water stations. Duplicates will represent a second sample collected in the field from the same location with a practical minimum of time lapse between them, while split samples will be collected for sediment in order to capture any additional variability in the field homogenization procedures. The duplicate samples will be preserved, packaged, and handled in the same manner as the primary samples. No equipment blanks or field blanks will be collected if dedicated sampling equipment or disposable equipment is used.

A field log book will be maintained to document all sampling activities. All notes will be made in indelible ink. Entries on each page will be initialed at the end of each page by the sampling crew member who entered the information. If any changes are made to the record, the original notation will be crossed out with a single line and initialed. Information to be recorded in the log book or on a designated field form is described in Section 5.0.

7.0 FIELD AND LABORATORY TESTING METHODS

Three environmental media will be collected during the spring 2008 sampling period. All samples will be transferred to the EPA Region 8 CLP laboratory, DataChem Laboratories, Inc., laboratory for analysis. These media include:

- Groundwater
- Surface Water
- Bed Sediment

Conventional elemental analyses are being contracted under separate contract mechanisms, and are governed by the QC program in place for the CLP program, with the exception of the Modified Analysis Requests presented in Appendix H. The CLP protocols established in ILMO5.4 are amenable to routine good laboratory practices and include corrective actions consistent with routine laboratory quality systems. As these conventional determinations are contracted separately from the current vehicle, Tetra Tech has described the analytical requirements of the CLP protocols, but their actual analyses are outside the scope of the current Work Assignment. Laboratory corrective action requirements and procedures are documented in the laboratory's quality assurance program. Current laboratory turnaround time is established at 21 calendar days.

7.1 Groundwater and Surface Water

Aqueous (groundwater and surface water) samples will be tested in the field for pH, specific conductance, and temperature using EPA Methods 150.1 (pH), 120.1 (Specific Conductance), and 170.1 (Temperature) using field instruments.

Analyses for surface water samples include dissolved and total metals (aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, silver, and zinc. The additional analytical suite includes: ferrous (iron⁺²), ferric (iron⁺³) by Hach/ICP-MS laboratory methods, sulfate (EPA 375.2), and dissolved organic carbon (SW846 Method 9060 analysis will be conducted on the field filtered samples. Therefore the result will be the amount of dissolved organic carbon.)

7.2 Sediment Extraction Method

Sediment samples must first be extracted into an aqueous solution to be analyzed. Several leaching procedures are available to evaluate metals mobility. Two of the more frequently used procedures, toxicity characteristics leaching procedure (TCLP) and synthetic precipitation leaching procedure (SPLP), require that solid waste be mixed with the appropriate extraction fluid and tumbled for 18 hours in a rotary agitator. SPLP is identical to the TCLP with regards to the sample processing and extraction process. The difference lies in the extraction fluid used. While the TCLP fluids are highly buffered and mildly acidic using acetic acid, the SPLP uses an extraction fluid based on the physical location of the site to be characterized (east or west of the Mississippi River). The solution used in the east is an unbuffered solution of sulfuric and nitric acids, at a slightly more acidic pH. The SPLP typically is employed to more closely simulate groundwater leaching effects than the TCLP. After the extraction, the liquid is filtered, acid digested on a hot plate, and analyzed for metals suite by inductively coupled plasma-mass spectroscopy (ICP-MS).

SPLP (EPA SW-846 Method 1312) will be used to evaluate the potential for leaching metals into ground and surface waters. This method provides a more realistic assessment of metal mobility under actual field conditions, i.e. what happens when it rains (or snows). The extraction fluid is intended to simulate precipitation. East of the Mississippi River the fluid is slightly more acidic at pH 4.20 reflecting the air pollution impacts of heavy industrialization and coal utilization. A pH of 5.00 is used west of the Mississippi reflecting less industrialization and smaller population densities. The SPLP is a method of choice when evaluating fate and transport of metals in a properly engineered waste land disposal facility from which municipal solid waste is excluded. For this same reason, the SPLP method is ideal for the chemical transport modeling.

7.3 EPA Analytical Method to Determine Chemical Concentrations

Analytical protocols described in the current EPA Contract Laboratory Program Statement of Work (CLP-SOW; ILMO5.4), ICP-MS allow sensitive, simultaneous determination of many elements in a short time frame using mass spectroscopy detection

in place of atomic emission spectroscopy. In general, ICP-MS exhibits greater sensitivity (lower detection limits) than other analytical instruments for most elements. The greatest disadvantage of ICP-MS is isobaric elemental interferences. These are caused by different elements forming atomic ions with the same nominal mass-to-charge ratio. Mathematical correction for interfering ions can minimize these interferences. For the sediment analyses, the ILMO5.4 conventional ICP approach will be utilized for aluminum, calcium, iron, and magnesium, as these elements are expected to be of sufficient concentration in the leachates to present difficulties using ICP-MS.

Table 7-1: Chemical Analysis required for Groundwater and Surface Water

Analyte	Total	Dissolved Fraction	Holding Time	Analytical Method	Quantitation Limits
Ferrous (Iron ⁺²)		X	ASAP	Hach 8146 based on SM3500-Fe.B.4c)	0.03 mg/L
Ferric (Iron ⁺³)		X	ASAP, 6 months (Calculated from Fe ²⁺ and Fe)	ILMO5.4 ICP-MS	NA
Iron	X		6 months, preserved	ILMO5.4 ICP-MS	10 µg/L
Aluminum	X	X	6 months, preserved	ILMO5.4 ICP-MS	20 µg/L
Arsenic	X	X	6 months, preserved	ILMO5.4 ICP-MS	1 µg/L
Barium	X	X	6 months, preserved	ILMO5.4 ICP-MS	10 µg/L
Cadmium	X	X	6 months, preserved	ILMO5.4 ICP-MS	5 µg/L
Calcium		X	6 months, preserved	ILMO5.4 ICP-MS	500 µg/L
Chromium	X	X	6 months, preserved	ILMO5.4 ICP-MS	2 µg/L
Copper	X	X	6 months, preserved	ILMO5.4 ICP-MS	2 µg/L
Lead	X	X	6 months, preserved	ILMO5.4 ICP-MS	1 µg/L
Magnesium		X	6 months, preserved	ILMO5.4 ICP-MS	500 µg/L
Manganese	X	X	6 months, preserved	ILMO5.4 ICP-MS	15 µg/L
Silver	X	X	6 months, preserved	ILMO5.4 ICP-MS	1 µg/L
Zinc	X	X	6 months, preserved	ILMO5.4 ICP-MS	2 µg/L
Sulfate (SO ₄)		X	28 days	EPA 375.2	3 mg/L
DOC		X	28 days preserved	SW846 9060	1.0 mg/L
TSS	X		7 days	SM 2540D	1.0 mg/L
pH		NA	ASAP Field Measurement	EPA 150.1	
Conductivity		NA	ASAP Field Measurement	EPA 120.1	
Temperature		NA	ASAP Field Measurement	EPA 170.1	
Stream Flow		NA	NA –Field Measurement	ASTM D3858-95	NA

Table 7-2: Chemical Analysis Required for Stream Sediment

Analytes	Total in leachate	Holding Time to leaching 1312	Holding Time to analysis of leachate	Analytical Method ILM05.4 (ICP-MS) (*ICP-AES)	
Aluminum	X	6 mos	6 mos preserved		20 µg/L
Arsenic	X	6 mos	6 mos preserved	X	1 µg/L
Barium	X	6 mos	6 mos preserved	X	10 µg/L
Cadmium	X	6 mos	6 mos preserved	X	5 µg/L
Calcium	X	6 mos	6 mos preserved	(*ICP-AES)	5,000 µg/L
Chromium	X	6 mos	6 mos preserved	X	2 µg/L
Copper	X	6 mos	6 mos preserved	X	2 µg/L
Iron Ferrous (Iron ⁺²), Ferric (Iron ⁺³)	X	ASAP	ASAP Fe ²⁺ Fe 6 mos preserved	Ferrous Iron SM3500-Fe.B.4c) Ferric Iron by calc. (Fe by *ICP-AES)	100 µg/L
Lead	X	6 mos	6 mos preserved	X	1 µg/L
Magnesium	X	6 mos	6 mos preserved	(*ICP-AES)	5000 µg/L
Manganese	X	6 mos	6 mos preserved	X	15 µg/L
Silver	X	6 mos	6 mos preserved	X	1 µg/L
Zinc	X	6 mos	6 mos preserved	X	2 µg/L
Sulfate (SO ₄)	X	28 days	28 days	Method 375.3	

Table 7-3: DataChem Preservation, Sample Quantities, and Bottle Type

Sample Matrix	Estimated No. of Samples	Total Metals ¹ Suite	Dissolved Metals ¹ Suite	Additional Analytical Suite ²
Ground Water	7			
Preservative and sample bottle volume required		Field filtered (0.45µm) 1L HDPE pH ≤2 w/HNO ₃	1L HDPE pH ≤2 w/HNO ₃	*DOC= field filtered (0.45µm), 500mL BR glass pH≤2 w/H ₂ SO ₄ , cool to 4°C; *Fe ²⁺ =500ml HDPE Amber w/ 2mL of HCl, cool to 4°C; *SO ₄ = 250 mL HDPE, cool to 4°C
Surface Water	36			
Preservative and sample bottle volume required		Field filtered (0.45µm) 1L HDPE pH ≤2 w/HNO ₃	1L HDPE pH ≤2 w/HNO ₃	*DOC= field filtered (0.45µm) 500mL BR glass, pH≤2 w/H ₂ SO ₄ , cool to 4°C; *Fe ²⁺ =500ml HDPE Amber w/ 2mL HCl, cool to 4°C; *SO ₄ = 250mL HDPE, cool to 4°C
Stream Sediment	36	SPLP (lab prepared and preserved)	SPLP (lab prepared)	SPLP leachate preparation followed by routine metals suite
Preservative and sample bottle volume required		SPLP leachate	SPLP leachates	16oz Amber Jar, cool to 4°C; after leaching, all leachates preserved according to the requirements for water above.

NOTES: HDPE High density polyethylene; BR = Boston round, wide mouth jar; SPLP = Synthetic Precipitation Leachate Procedure, conducted at the laboratory using SW846 Method 1312. All samples will be cooled to 4°C, but it is not required for metals analysis.

¹ Metals analytical suite includes: Aluminum, Arsenic, Barium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Silver, and Zinc

² Additional analytical suite includes: Ferrous (Iron⁺²), Ferric (Iron⁺³), Sulfate (Method 375.3), and Dissolved Organic Carbon (9060A)

8.0 MODEL DEVELOPMENT AND CALIBRATION

Establishing a relationship between the in-stream water quality targets and source loading is a critical component of the source loading assessment. Identifying the cause and effect relationship between pollutant loads and water quality response is necessary in order to evaluate the loading capacity of the receiving water bodies. The loading capacity is the

amount of pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the model development for evaluating metals (primarily cadmium and zinc) loading in the Silver Creek watershed.

8.1 Modeling Approach

Tetra Tech's Acid Mine Drainage Affected Stream (AMDS1D) model consists of four sub-models: 1) steady state flow estimation by the Manning equation; 2) suspended sediment transport; 3) dissolved solute transport; and 4) the chemical equilibrium and kinetic speciation model. The model can be used for a single river reach or a river with multiple tributaries. The model simulates one class of suspended sediment in the river system. A toxic chemical reaction sub-model for streams and sediment was developed based on equilibrium theory and is coupled with the contaminants transport model and the suspended sediment transport model. Chemical reactions among contaminants and the exchange of contaminants between the water column and the bottom sediment are simulated.

The AMDS1D model was coupled with the equilibrium chemical speciation model to simulate water quality conditions in Silver Creek. The goal of this modeling study is to evaluate potential future remediation scenarios to assess the load reductions required for Silver Creek to meet the water quality endpoints for metals (primarily dissolved cadmium and zinc). The model will be configured based on the following criteria:

- Spatial and temporal distribution of observed data
- Hydrology and geochemistry of the investigated site
- Contaminant sources in the watershed
- Interaction between water column and sediment layer
- Model capability to assess future possible remedial scenarios

8.2 Conceptual Model

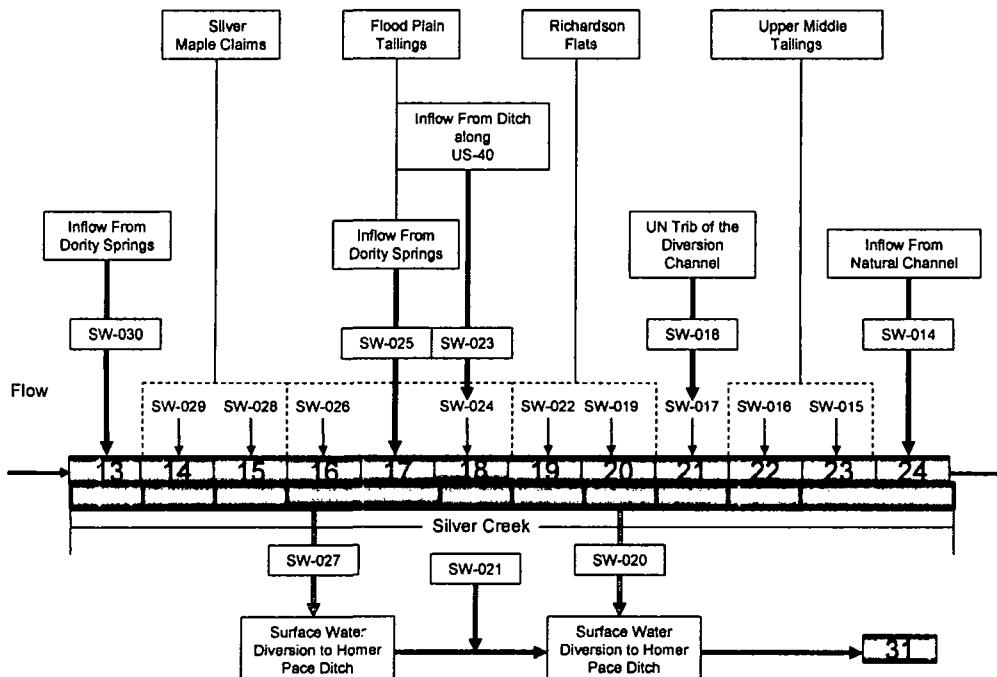
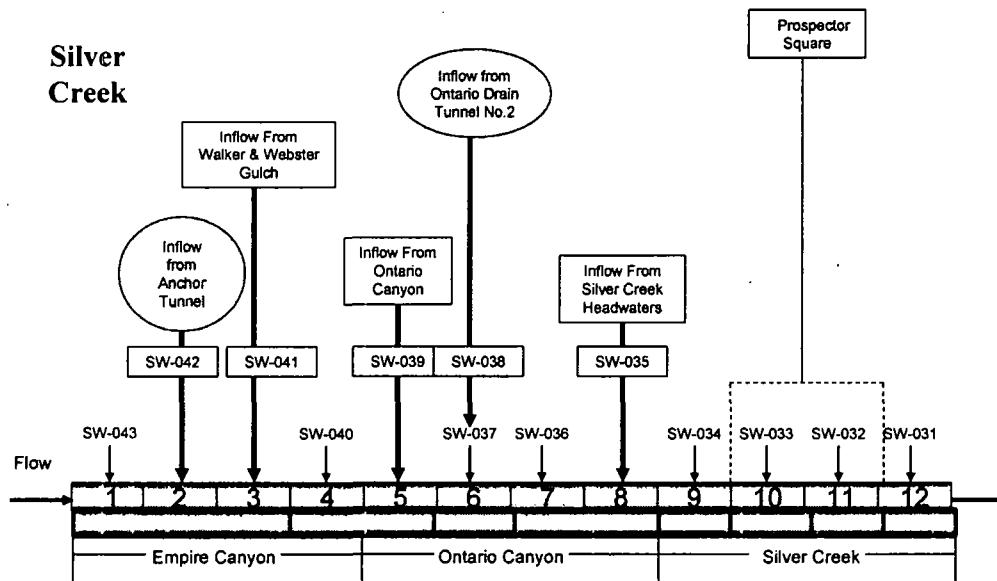
The existing water quality monitoring data from Silver Creek was examined to identify the critical flow condition that could carry high dissolved cadmium and zinc concentrations in the stream flow. Based on the 2001-2006 STORET data collected by Utah DEQ, the critical condition occurs during the high flow condition from spring snow melt. Consequently, the targeted modeling period focuses on the early spring period. After the available data sets were examined, it was determined that none were adequate for building the chemical speciation model. Therefore, a specific spring sampling event was needed to facilitate building the speciation model.

The stream was segmented for the purpose of optimal model performance and source representation. The segmentation was performed based on the following criteria:

- Geometric characteristics of stream reaches including slopes, cross-sectional areas, depths and widths
- The collection of optimal sample locations for water quality and flow samples during spring runoff conditions

- The location of the known point sources to the stream
- Stream travel time
- The ability to co-locate sediment samples with water quality data

The representation of surface water segments is illustrated in Figure 8-1. Each in-stream/sediment segment is represented by computational compartments for evaluating in-stream and sediment transport, and associated chemical reactions. Segmentation of the sediment layer in the model was based on the assumption that sediment and water quality samples would be co-located; therefore, sediment compartments were assigned the same length as the in-stream segments.



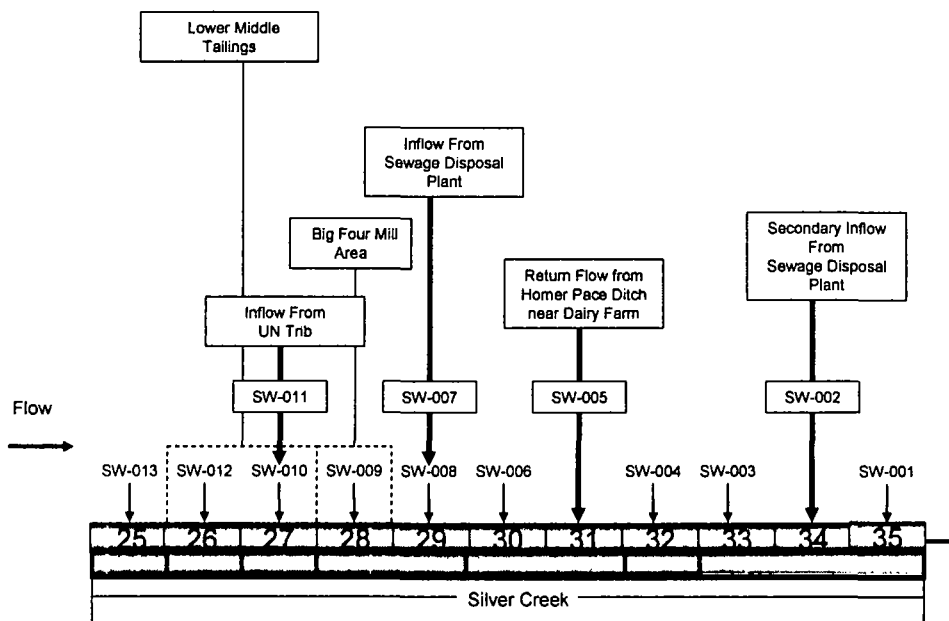


Figure 8-1: Silver Creek Watershed Conceptual Model Design

Two types of metals loadings to the streams were considered. The first type is the loading from known locations, including tributary inflows and water treatment plant discharges. The second type is the loading from the unknown/undetermined locations and areas. Unknown locations mainly included groundwater inflows and/or unmeasured surface inflows. The following known sources were considered in the model for the Silver Creek section:

- Ontario and Anchor Tunnel
- Prospector Square
- Silver Maple Claims
- Floodplain tailings
- Richardson Flats
- Upper Middle Meadow tailing piles
- Lower Middle Meadow tailing piles
- Old Big Four mill sites
- Wastewater treatment plant
- Irrigation return flow

The Silver Creek water quality model is composed of 35 individual model “cells” that represent the hydrologic and chemical dynamics that occur within 35 delineated stream reaches. Inputs and outputs of each cell will be determined by the hydrology and pollutant sources affecting the stream reach that each cell represents. Figure 8-2 displays hydrologic inputs and outputs, as well as the chemical and physical reactions calculated within one model cell.

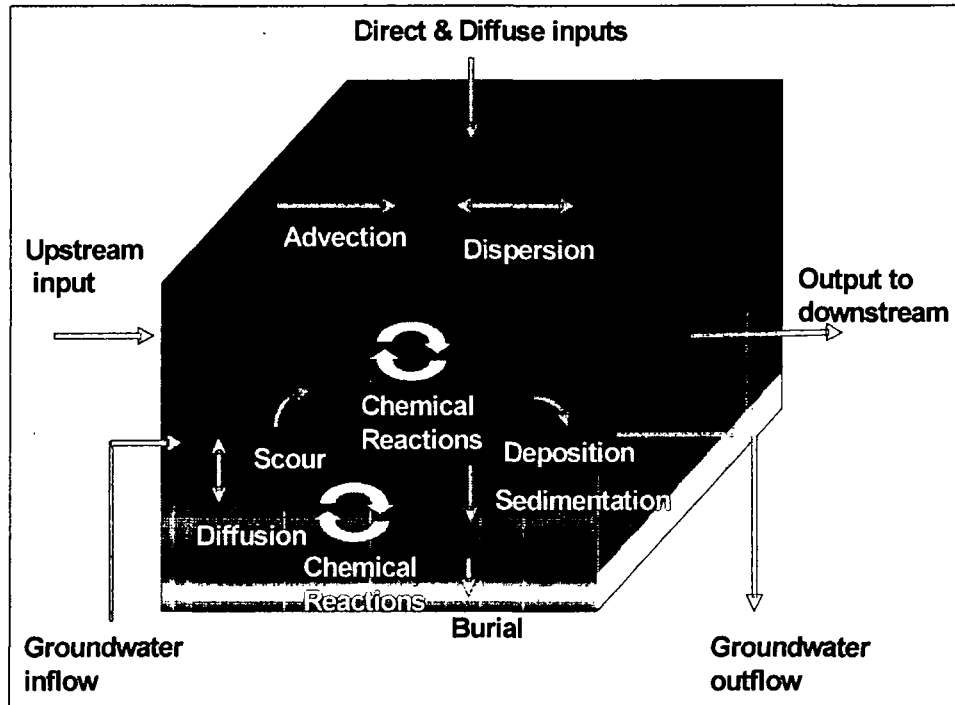


Figure 8-2: Conceptual Diagram of the Water Quality Model

Each modeled cell receives water and chemical constituents from the cell directly upstream. Once the chemical constituents are transported to the cell, they are subject to various chemical and physical reactions. Chemical reactions are modeled to occur in both the water column and in the sediment layer. Chemical components are divided into different chemical phases based on reaction constants. These phases can be dissolved, solid, adsorbed and gas phases. For example, dissolved iron can precipitate into the solid phase depending on the dissolved oxygen and pH conditions of the solution. Dissolved carbonate can be released into air as CO_2 , which depends on the partial pressure of CO_2 in the air and the solution's pH. Dissolved metals can adsorb to mineral surfaces, such as iron hydroxide, aluminum hydroxide, and other natural particles existing in streams. Depending on the stream's chemical composition and flow conditions, some of these chemical constituents could deposit onto sediment or be re-suspended from the stream bottom.

Chemical constituents are added with the inflow from modeled tributaries or point and nonpoint sources. Constituents can also be subtracted as losses to irrigation withdrawals

or groundwater outflow. Chemical and physical changes within the cells will change the volume and concentration of constituents in the water column. Water and chemicals then leave the cell and are transported to the next downstream cell. Bedload transport of sediment between cells will not be modeled.

In addition to the loadings to the stream from the surrounding area, sediment can be a source and/or sink of inorganic solutes. The equilibrium speciation concept will be applied to the sediment compartment to evaluate dissolved cadmium and zinc. Active sediment depth will be assigned to the section of the sediment that was assumed to be participating in relatively “fast” reactions. Sediment sample concentrations will be measured using partial digestion methods so that only inorganic solutes adsorbed on the surfaces of hydrous oxides will be analyzed. These concentrations will be used as the starting point of the model. The model uses density and porosity of the active sediment to estimate dissolved inorganic solutes, including dissolved zinc and cadmium in solution within the sediment, and adsorbed inorganic solutes including zinc and cadmium on hydrous oxides.

8.3 Hydrology Calibration

A simplified flow balance hydrology will be used for the modeling effort. Based on the observed flow data, flow balance hydrology will be calculated from the June 2 through 6, 2008 dataset. The sampling event will be conducted under snowmelt runoff conditions.

At each stream flow location, dimensions of the stream channel will be obtained. For modeling purposes, an assumption that the stream channel is trapezoidal in shape. The side slope (Z) of the channel will be calculated based on the stream channel dimensions. The Manning’s roughness value (n) for the streams has been determined as 0.035. Based on the length and elevations observed at the starting and ending points of the stream from the topographic map, the slope (S) of the stream is calculated as 0.007 for the floodplain portion of Silver Creek. The slope for the upper portion of the watershed will be calculated based on elevation data. A uniform depth (d) of 0.5 feet will be assumed for the entire stream channel. Based on the above mentioned assumptions and using Manning’s equation, the width (b), the cross sectional area (A) of the trapezoidal channel can be determined.

The hydrology of the model segments will be calibrated using a flow balance calculation between sample points, incorporating flows from the sources and tributary streams that were sampled. Typically, model segmentation will match sampling locations; however in some situations where sample locations spanned greater distances the model will be segmented into two or three cells. In this situation, the flow balance will still be calculated between sampling points and then equally distributed among the modeling segments. Losses to surface water flow between sample points will be assumed to be from groundwater recharge; while increases in surface water flow between sample points will be assumed to be from additional groundwater baseflow.

8.4 Water Quality Calibration

The conceptual water quality model for Silver Creek will be calibrated using the June, 2008 sampling dataset. The mass of cadmium and zinc in the stream is accounted for through inflow from tributaries and point/non-point sources, or withdrawal to irrigation and/or groundwater outflow. The model simulates the chemical speciation of these metals using an equilibrium thermodynamic database from USEPA's MINTEQA4 (Allison et. al. 1991). The distribution between dissolved and particulate forms of the two metals will be adjusted through the sediment deposition-resuspension process. The known sources of water quality constituents are included in the model using actual observation values, whereas estimated values from mass balance calculation are used for unknown sources. The high-flow model will be calibrated using the observed water quality data.

Specifically, water quality calibration will be conducted for the following parameters: 1) pH, which was selected as a master variable for all chemical reactions considered in the model (which include acid/base, precipitation/dissolution, gas solubility, adsorption/desorption and redox reactions); 2) distribution between colloidal and dissolved species of cadmium and zinc in Silver Creek; 3) distribution between particulate (colloidal) and dissolved phases of iron, aluminum, and manganese, which provides adsorption surface to attenuate dissolved cadmium and zinc activity in solution and sediment; 4) dissolved calcium and magnesium, which are major conservative cations that exist in relatively high concentrations and control ionic strength and activity coefficients; 5) total sulfate, which is the major anion in mining-affected streams and affects ionic strength and activity coefficients and participates in complex reactions with metals; 6) total suspended solids (TSS), which provide additional adsorption surface for trace metals in the model.

Calibration for the water quality constituents will be performed mainly by a combination of the following parameters in the model.

- The ratio of incoming ferric and ferrous iron to the stream
- Metal/sediment settling velocity
- Boundary stress below which deposition takes place
- Metal/sediment re-suspension rate
- Boundary stress above which re-suspension occurs
- Loads withdrawn by groundwater outflow
- Diffuse reaction between water column and sediment
- Inflow concentration for unknown non-point/groundwater inflows
- The partition coefficients of cadmium and zinc with TSS

The reaction constants, acidity constants, stability constants, solubility products, and adsorption constants used for chemical reactions in the chemical reaction model will be unmodified from the MINEQL and MINTEQ thermodynamic database, and literature values.

9.0 DOCUMENTATION AND RECORDS

Thorough documentation of all field sample collection and handling activities is necessary for proper processing in the laboratory and, ultimately, for the interpretation of study results. Field sample collection and handling will be documented in writing (for each location sampled) using a field log notebook which will record all sampling activities. The following information will be recorded:

- Names of field personnel
- Date/time of measurement
- Measurement identification location (transect, station, etc.)
- GPS coordinates
- General weather conditions (e.g. hot, windy, no precipitation)
- Description and location of nearby features (e.g. shafts, building foundations, cribbing), if visually present
- Description and location of water drainage paths, if present near the measurement location
- General description of adjacent vegetation conditions
- Sample identification, sample collection location, and collection time, if sample is collected
- Any problems encountered or deviations in sample collection methods
- Description of any unusual circumstances
- Photo documentation details, if necessary

A description of each sample at each station will be recorded on a Chain of Custody. The form will document the sampling date, time, sampler's name, sampling site location/description, and sample description. The chain of custody will be submitted to the laboratory with the samples for analysis, and will document transfer of custody to the laboratory. All entries will be made in ink and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark, which is initialed and dated by the sampler/recorder. All portions of the chain of custody records will be filled out completely and any additional issues or comments will be added in the space provided for comments at the bottom of the form. A copy of the chain will be retained by the sampler, and that copy will be faxed to the laboratory. The Tetra Tech QC Officer or designee will review copies of custody records for appropriateness and for assessment of any documentation related deficiencies.

A Sample Identification Label (to be placed on the sample bottle/container) will be completed to accompany each sample throughout the chain of custody. The label will document the project name, sampling site location, and the sampling number. All entries will be made in indelible ink and will coincide with specimen and sample information in the field log notebook.

Samples will be hand delivered from the field to the sample analysis laboratory via Tetra Tech staff. Specification for retention of field samples by the receiving location are outside the scope of this document, but it is assumed that samples will be retained for a

period of at least one month following Tetra Tech's receipt of the final analysis report. Samples will be disposed of in accordance with federal and local regulations.

The Tetra Tech WALs will maintain files, as appropriate, as repositories for information and data used in the preparation of any reports and documents during the project and will supervise the use of materials in the project files. The following information will be included:

- Any reports and documents prepared.
- Contract and work assignment information.
- Project FSP.
- Results of technical reviews, data quality assessments, and audits.
- Communications (memoranda; internal notes; telephone conversation records; letters; meeting minutes; and all written correspondence among the project team personnel, subcontractors, suppliers, or others).
- Maps, photographs, and drawings.
- Studies, reports, documents, and newspaper articles pertaining to the project.
- Special data compilations.
- Spreadsheet data files: physical measurements, analytical chemistry data (hardcopy and on diskette).

Copies of the field log book will be supplied to the WALs at the close of the sampling activities. These data will be used in conjunction with chains of custody, laboratory receipt acknowledgments and inspection checklists to compile the sampling event reports. Formal reports submitted to EPA that are generated from the data will be maintained at Tetra Tech's Fairfax office in the central file (diskette and hard copy). The data reports will include a summary of the types of data collected, sampling dates, and any problems or anomalies observed during sample collection.

No supplemental quality assurance reports are included in the current work assignment. However, documentation of deficiencies in data or significant departures from the project requirements will be documented and submitted to the WALs and the WAM by the QAO or her designee.

10.0 ASSESSMENTS AND RESPONSE ACTIONS

Tetra Tech's QA program includes both performance and system audits as independent checks on the quality of the data obtained from sampling, analysis, and data gathering activities. Every effort will be made to have the audit assess a measurement process in normal operation. Either type of audit may show the need for corrective action. The essential steps in the QA program are as follows:

- Identify and define the problem.
- Assign responsibility for investigating the problem.
- Investigate and determine the cause of the problem.
- Assign and accept responsibility for implementing appropriate corrective action.
- Establish effectiveness of and implement the corrective action.
- Verify that the corrective action has eliminated the problem.

Many of the technical problems that might occur can be solved on the spot by the staff members involved; for example, by modifying the technical approach, repairing instrumentation that is not working properly, or correcting errors or deficiencies in documentation. Immediate corrective actions form part of normal operating procedures and are noted in records for the project. Problems not solved this way require more formalized, long-term corrective action. If quality problems that require attention are identified, Tetra Tech will determine whether attaining acceptable quality requires either short- or long-term actions and will notify the WAM.

Perhaps the single most important part of any QA program is a well-defined, effective policy for correcting quality problems. The WALs have primary responsibility for monitoring the activities of this project and identifying or confirming any quality problems. These problems will also be brought to the attention of the Tetra Tech QA Officer, who will initiate the corrective action system described above, document the nature of the problem, and ensure that the recommended corrective action is carried out. The Tetra Tech QA Officer has the authority to stop work on the project if problems affecting data quality that will require extensive effort to resolve are identified. The WAM and WAL will be notified of major corrective actions and stop work orders.

The Field Task Leaders will have primary responsibility for ensuring the proper working order of the field equipment. If problems are noted that will affect data quality and they cannot be addressed by the Task Leaders immediately, the WAL and WAM will be notified. The WAM will have primary responsibility for monitoring the activities of this project and identification/confirmation of any quality problems. These problems will be brought to the attention of the Tetra Tech QA Officer who will initiate the corrective action system described above and verify that the corrective action has been appropriately addressed to eliminate the problem.

Data validation and review services provide a method for determining the usability and limitations of data, and provide a standardized data quality assessment. All field record

forms will be reviewed by the Tetra Tech WALs (assisted by the QC Officer, as needed) for completeness and correctness. Tetra Tech will be responsible for reviewing data entries and transmittals for completeness and adherence to QA requirements. Data quality will be assessed by comparing entered data to original data or by comparing results with the measurement performance criteria summarized in Section 2.2 to determine whether to accept, reject, or qualify the data. Results of the review and validation processes will be reported to the WAM. Analytical data provided by the laboratories will be reviewed prior to its release by the Laboratory QA Officer, and Laboratory Manager, and will include a certifying statement that the data included have been reviewed for compliance with the reference methods and this FSP.

The submission of samples to the laboratory will include a copy of the Chain-of-Custody form with sampling time, date, sample location, and analyses to be completed. This information will be checked by the Field Task Leaders on receipt of data reports from the laboratory to ensure holding times have not been exceeded. To prevent confusion, all bottles submitted for analysis will be clearly marked and checked before submission to the laboratory

11.0 REFERENCES

- ASTM, 1995, Method D3858-95, *Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method*; American Society for Testing and Materials, West Conshohocken, PA.
- EPA, 1988, "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA," EPA/540/G-89/004, Office of Emergency and Remedial Response, October.
- EPA, 2004, "USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review," EPA-540/R-04-004, Office of Solid Waste and Emergency Response, October.
- EPA, 2005, "Richardson Flat Tailings Site, Park City, Utah, Record of Decision," July.
- EPA, 2006, "Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4," Office of Environmental Information, EPA/240/B-06/001, February.
- UDEQ – DERR, 2002, "Innovative Assessment Analytical Results Report, Lower Silver Creek, Summit County, Utah," October.
- UDEQ – DWQ, 2004, "Silver Creek: Total Maximum Daily Load for Dissolved Zinc and Cadmium," August.
- U.S. Geological Survey, 1989, "Gold deposits in the Park City Mining District, Utah," U.S. Geological Survey Bulletin 1857.
- U.S. Geological Survey, 2004, "Principal Locations of Metal Loading from Floodplain Tailings, Lower Silver Creek, Utah," April.
- Utah Geological Society, 1968, "Ore Deposits of the Park City District."
- U.S. Geological Survey, 1980, "National Handbook of Recommended Methods for Water-Data Acquisition," August.
- Williams, F. T., 1916, "Park City Mines for 1915", Salt Lake Mining Review, January.

APPENDIX A

**EPA ERT SOP NUMBER 2013 – SURFACE WATER
SAMPLING**

EPA/540/P-91/005
OSWER Directive 9360.4-03
January 1991

COMPENDIUM OF ERT SURFACE WATER AND SEDIMENT SAMPLING PROCEDURES

Sampling Equipment Decontamination

☒ Surface Water Sampling

Sediment Sampling

Interim Final

Environmental Response Team
Emergency Response Division

Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, DC 20460



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2.0 SURFACE WATER SAMPLING: SOP #2013

2.1 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) is applicable to the collection of representative liquid samples, both aqueous and nonaqueous from streams, rivers, lakes, ponds, lagoons, and surface impoundments. It includes samples collected from depth, as well as samples collected from the surface.

2.2 METHOD SUMMARY

Sampling situations vary widely and therefore no universal sampling procedure can be recommended.

However, sampling of both aqueous and non-aqueous liquids from the above mentioned sources is generally accomplished through the use of one of the following samplers or techniques:

- Kemmerer bottle
- bacon bomb sampler
- dip sampler
- direct method

These sampling techniques will allow for the collection of representative samples from the majority of surface waters and impoundments encountered.

2.3 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Once samples have been collected, follow these procedures:

1. Transfer the sample(s) into suitable labeled sample containers.
2. Preserve the sample if appropriate, or use pre-preserved sample bottles.
3. Cap the container, put it in a Ziploc plastic bag and place it on ice in a cooler.
4. Record all pertinent data in the site logbook and on a field data sheet.

5. Complete the chain of custody form.

6. Attach custody seals to the cooler prior to shipment.

7. Decontaminate all sampling equipment prior to the collection of additional samples.

2.4 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary interferences or potential problems with surface water sampling. These include cross-contamination of samples and improper sample collection.

- Cross-contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Refer to ERT SOP #2006, Sampling Equipment Decontamination.
- Improper sample collection can involve using contaminated equipment, disturbance of the stream or impoundment substrate, and sampling in an obviously disturbed area.

Following proper decontamination procedures and minimizing disturbance of the sample site will eliminate these problems.

2.5 EQUIPMENT/APPARATUS

Equipment needed for collection of surface water samples includes:

- Kemmerer bottles
- bacon bomb sampler
- dip sampler
- line and messengers
- sample bottle preservatives
- Ziploc bags
- ice
- cooler(s)
- chain of custody forms, field data sheets

- decontamination equipment
- maps/plot plan
- safety equipment
- compass
- tape measure
- survey stakes, flags, or buoys and anchors
- camera and film
- logbook/waterproof pen
- sample bottle labels

2.6 REAGENTS

Reagents will be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

2.7 PROCEDURES

2.7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies are needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or preclean equipment, and ensure that it is in working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site-specific health and safety plan.
6. Use stakes, flags, or buoys to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

2.7.2 Sampling Considerations

Representative Samples

In order to collect a representative sample, the hydrology and morphometrics (e.g., measurements

of volume, depth, etc.) of a stream or impoundment should be determined prior to sampling. This will aid in determining the presence of phases or layers in lagoons or impoundments, flow patterns in streams, and appropriate sample locations and depths.

Water quality data should be collected in impoundments to determine if stratification is present. Measurements of dissolved oxygen, pH, and temperature can indicate if strata exist which would effect analytical results. Measurements should be collected at 1-meter intervals from the substrate to the surface using an appropriate instrument, such as a Hydrolab (or equivalent).

Water quality measurements such as dissolved oxygen, pH, temperature, conductivity, and oxidation-reduction potential can assist in the interpretation of analytical data and the selection of sampling sites and depths anytime surface water samples are collected.

Generally, the deciding factors in the selection of a sampling device for sampling liquids in streams, rivers, lakes, ponds, lagoons, and surface impoundments are:

- Will the sample be collected from the shore or from a boat on the impoundment?
- What is the desired depth at which the sample is to be collected?
- What is the overall depth and flow direction of river or stream?

Sampler Composition

The appropriate sampling device must be of a proper composition. Samplers constructed of glass, stainless steel, PVC or PTFE (Teflon) should be used based upon the analyses to be performed.

2.7.3 Sample Collection

Kemmerer Bottle

Kemmerer bottle (Figure 1, Appendix A) may be used in most situations where site access is from a boat or structure such as a bridge or pier, and where samples at depth are required. Sampling procedures are as follows:

1. Using a properly decontaminated Kemmerer bottle, set the sampling device so that the sampling end pieces are pulled away from the sampling tube, allowing the substance to be sampled to pass through this tube.
2. Lower the pre-set sampling device to the predetermined depth. Avoid bottom disturbance.
3. When the Kemmerer bottle is at the required depth, send down the messenger, closing the sampling device.
4. Retrieve the sampler and discharge the first 10 to 20 mL to clear any potential contamination on the valve. Transfer the sample to the appropriate sample container.

Bacon Bomb Sampler

A bacon bomb sampler (Figure 2, Appendix A) may be used in similar situations to those outlined for the Kemmerer bottle. Sampling procedures are as follows:

1. Lower the bacon bomb sampler carefully to the desired depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut.
2. Release the trigger line and retrieve the sampler.
3. Transfer the sample to the appropriate sample container by pulling the trigger.

Dip Sampler

A dip sampler (Figure 3, Appendix A) is useful for situations where a sample is to be recovered from an outfall pipe or along a lagoon bank where direct access is limited. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer's instructions.
2. Extend the device to the sample location and collect the sample.
3. Retrieve the sampler and transfer the sample to the appropriate sample container.

Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the surface. This method is not to be used for sampling lagoons or other impoundments where contact with contaminants are a concern.

Using adequate protective clothing, access the sampling station by appropriate means. For shallow stream stations, collect the sample under the water surface pointing the sample container upstream. The container must be upstream of the collector. Avoid disturbing the substrate. For lakes and other impoundments, collect the sample under the water surface avoiding surface debris and the boat wake.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

2.8 CALCULATIONS

This section is not applicable to this SOP.

2.9 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA/QC procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

2.10 DATA VALIDATION

This section is not applicable to this SOP.

2.11 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures.

More specifically, when sampling lagoons or surface impoundments containing known or suspected hazardous substances, take adequate precautions. The sampling team member collecting the sample should not get too close to the edge of the impoundment, where bank failure may cause him or her to lose their balance. The person performing the sampling should be on a lifeline and be wearing adequate protective equipment. When conducting sampling from a boat in an impoundment or flowing waters, follow appropriate boating safety procedures.

Figure 1: Kemmerer Bottle

SOP #2013

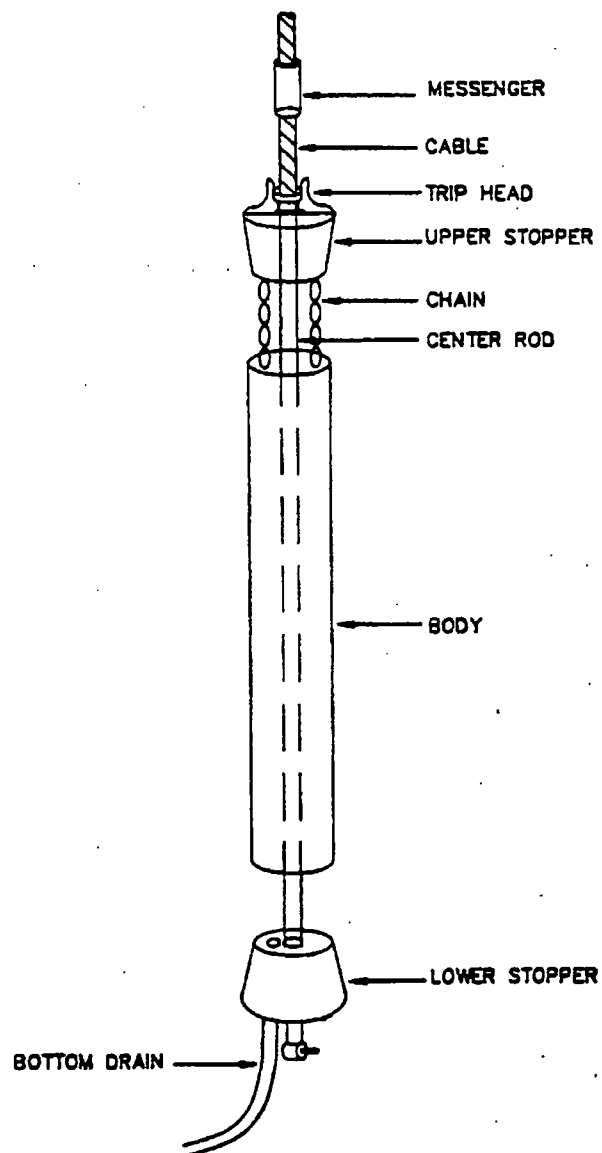


Figure 2: Bacon Bomb Sampler

SOP #2013

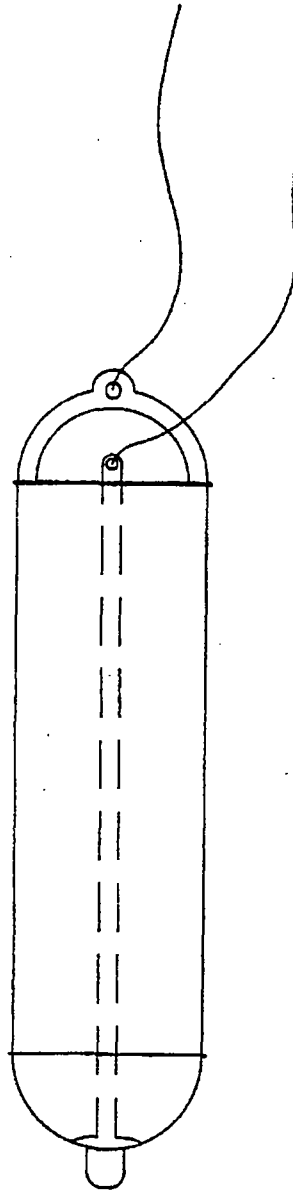
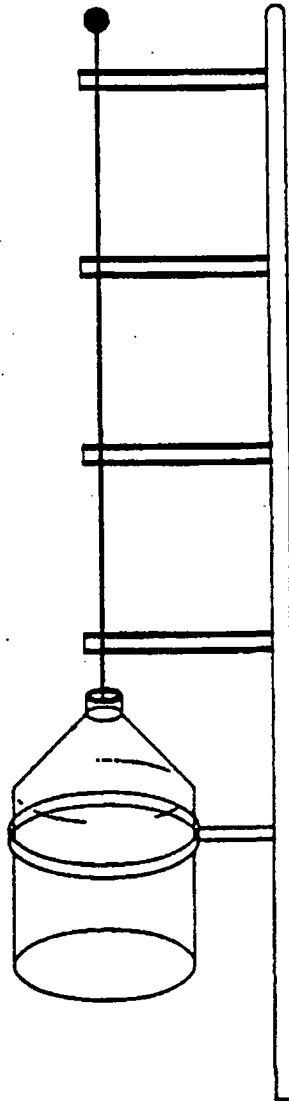


Figure 3: Dip Sampler

SOP #2013



APPENDIX B
SOP NUMBER 3.2 – WELL DEVELOPMENT

SOP #3.2
STANDARD OPERATING PROCEDURE
FOR
WELL DEVELOPMENT

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SOP #3.2
STANDARD OPERATING PROCEDURE
FOR
WELL DEVELOPMENT
ABSTRACT

This document describes general well development procedures for use by EPA Project Managers conducting hydrogeological investigations. Adequate well development is a most critical part of a ground water monitoring program. Proper well development minimizes the introduction of bias into the sampling effort. Proper development ensures good hydraulic connection between the aquifer and the well, and minimizes the amount of particulate matter (turbidity) in the ground water.

Recommended monitoring well development methods require surging, bailing, or pumping and backwashing to encourage flow reversal through the well screen, followed by removal of the fine sediments from the well casing. The pumping rate during development should be greater than pumping rates anticipated during subsequent purging and sampling, and should exceed the natural ground water flow rate. Development should continue until clear, sediment-free formation water is produced.

Turbidity must be monitored during development and must stabilize before development is deemed complete. The goal for development is to reach a level of 5 NTU turbidity during subsequent purging for sampling. Other water quality parameters including pH, specific conductance, and temperature should also be monitored during development to assess stabilization of the system. Turbidity is the best indicator of adequate well development, and is, therefore, the most critical parameter to monitor. In cases where wells are screened in low-yielding, water-bearing units, acceptably low turbidity levels may not be achievable. However, excess turbidity can also result from inappropriate well design or construction practices. It is the responsibility of the well owner's contractor to demonstrate that the well has been constructed properly and all reasonable efforts have been made to develop the well to achieve low turbidity. Finally, well development must be thoroughly documented to verify that foreign materials have been removed, representative formation water has entered the well screen, and turbidity and other field parameters have stabilized.

SOP #3.2
STANDARD OPERATING PROCEDURE
FOR
WELL DEVELOPMENT

1.0 INTRODUCTION AND PURPOSE

Every drilling method disturbs the aquifer materials around the well bore to some degree. Development attempts to restore the aquifer's natural hydraulic conductivity and geochemical equilibrium near the well such that representative samples of ground water can be collected. This is accomplished by removal of water and drilling fluids from the well casing, sand pack, and borehole walls along the screened interval. The major goal of well development is to allow low turbidity formation water to enter the well screen for sampling.

2.0 REQUIREMENTS FOR IMPLEMENTATION

2.1 Assumptions

This Standard Operating Procedure (SOP) identifies the basic components for development of most monitoring wells completed with a screened and sandpacked interval across from an unconsolidated water-bearing zone. This SOP is not applicable to wells with open-hole completions in bedrock. Some open-hole completions should not be aggressively developed by surging or physical contact with the borehole walls as described in this SOP, due to potential damage to the formation. However, some degree of development to remove fine-grained materials is desirable in a well-consolidated formation. Information regarding development of open-hole completions can be found in Driscoll, 1986.

The activities described in this SOP are based on the assumption that the well has been properly designed and installed (see Region VIII SOP on well design and installation, and information provided in ASTM Standard 5092-90.).

2.2 Options for Development

Several options for approach, equipment, and materials are presented in this SOP for well development. Section 3.0 of this SOP describes the steps and equipment required for development and identifies the criteria for determining when development is complete. The site-specific detail generally required for approval of a Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP), or Field Sampling Plan (FSP) is not included because site-specific and well-specific conditions must be evaluated to select the most appropriate options. When referencing this SOP in a QAPP, SAP or FSP, the equipment, materials, and detailed approach selected for the site must also be specified.

Due to the variability of site-specific conditions, well designs, and drilling methods, a complete description of all procedures and options for development is beyond the scope of this SOP. However, Section 3.2 of this SOP summarizes the three most applicable procedures. These three procedures are 1) surging with a surge block, 2) bailing, and 3) pumping, overpumping and backwashing with a pump. A combination of these three procedures may also be used. The EPA publication entitled "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells" (Aller, 1991) is recommended for more detailed development procedures.

3.0 WELL DEVELOPMENT STRATEGY

The purpose of development is to attempt to restore the aquifer's natural hydraulic conductivity and geochemical equilibrium near the well such that representative samples of ground water can be collected. Development is accomplished by pumping and surging the well to remove fine-grained material. Introduced fluids that are not representative of in-situ ground water conditions are also removed from the casing and the saturated interval during development. Proper development coupled with proper well design and installation should minimize the amount of purging required before sample collection.

Factors that affect well development are presented in Section 3.1. The criteria for deciding that development has been adequate are discussed in Section 3.2. Several methods for development of medium- to high-yield wells are presented in Section 3.3. Development of low-yield wells is discussed in Section 3.4, and general information necessary to plan development activities is summarized in Section 3.5.

3.1 Well Development Factors

Many factors affect development, including formation characteristics, drilling methods, well design, and the method used for development. The effects of formation characteristics, drilling methods and well design are discussed in the paragraphs below. Development methods are discussed in Section 3.3.

More permeable formations are easier to develop than less permeable formations. Fine-grained formations that contain abundant silt and clay are the most difficult to properly develop. Development of interbedded formations with different permeabilities results in preferential development of the zones with higher permeabilities. A greater proportion of water is subsequently produced from these zones during purging and sampling. However, this greater proportion represents the more productive zones with faster aquifer flow and recharge rates.

Different drilling methods can affect the borehole differently. Auger drilling can smear clays along the borehole wall in the completion interval, and mud rotary drilling produces a mudcake on the borehole wall that can penetrate a permeable formation by several inches. Removal of these clays and mudcake may require both a longer development time, and removal of a larger volume of fluid than is ordinarily expected for permeable formations.

Well design can affect the development procedure, especially the size of the borehole and the well casing. Larger diameter wells (i.e., 4-inch diameter or

greater) are generally easier to develop than smaller diameter wells (i.e., 2-inch diameter) because a greater variety of equipment is available for development, and because more water can be pumped from a larger diameter well. Sufficient energy and velocity must be provided during development to effectively remove the fine particulate material from the interface between the filter pack and the natural formation. It is generally easier to obtain equipment that can provide sufficient energy and velocity for larger diameter wells.

The thickness of the filter pack can also affect the time required for development. The thicker the filter pack, the more difficult it is to remove the fine particulate material. A small diameter well installed in a large borehole can be difficult to develop because sufficient energy and flow velocity through the thick filter pack cannot be developed in the small diameter well. Although the height of the filter pack above the top of the screen can influence the horizontal influence of surging, the impact has been demonstrated to be negligible (Driscoll, 1986).

The references cited in this section provide recommendations on filter pack thickness and design. A Region VIII SOP on monitoring well design and installation is under development, and will include guidelines for filter pack design.

3.2 Development Acceptance Criteria

Development should continue until clear, sediment-free formation water is produced. The best method available to evaluate the effectiveness of development is to measure turbidity. A major goal of well development is to produce a well that yields ground water samples of acceptably low turbidity. Excess turbidity may alter water quality and result in erroneous chemical analyses (particularly for unfiltered metals samples that require acid preservation). EPA Region VIII requires that turbidity be monitored during development, and strongly recommends that a goal of 5 nephelometric turbidity units (NTUs) be attempted. This goal may not always be appropriate or obtainable, but should be achievable in most wells correctly installed in relatively permeable formations.

Wells that do not meet the 5 NTU goal will be carefully evaluated by EPA to identify the cause of the turbidity. For wells with high turbidity, it must be demonstrated that the well was constructed properly and all reasonable efforts have been expended to develop the well. Installation of the screened interval across a clay-rich or silt-rich zone will often produce turbid water that can never meet the turbidity goal of 5 NTU. All development data must be carefully documented for all wells. If the 5 NTU goal cannot be met, the well installation

and development data must be presented to EPA for evaluation. Data regarding the volume of water produced and the stability of the turbidity measurements is especially important. If the formation water is turbid, development to meet the 5 NTU goal was attempted, and stability was documented at an NTU greater than 5, EPA may accept the stabilized NTU for use at that well. Development should continue until turbidity stabilizes, preferably at 5 NTU or less. Development should continue as long as turbidity is decreasing, if practical.

Other water quality field parameters such as pH, specific conductance, and temperature should also be monitored periodically during development to provide supplemental information regarding ground water conditions. These parameters should also stabilize before development is stopped. A standard method for measuring turbidity is described in ASTM D:1889. Methods for measuring other parameters should be as described in the manufacturer's user's manual for the specific instrument.

To demonstrate stabilization of a parameter, the acceptable range of field parameter measurements and the volume of water developed between these field parameter measurements must be established. The acceptable range of field parameter measurements is set at 10 percent of specific conductance and temperature, 20 percent of the turbidity values, and 0.2 units for pH. The volume of water between field parameter measurements should be one half casing volume. The minimum volume of water over which stabilization should be demonstrated is one casing volume, with three measurements.

In the event that additional water was added to the borehole or well during installation or development, two to three times the volume of water added must also be removed.

3.3 Well Development Methods for Medium to High-Yield Wells

The purpose of development is to remove the fine particulate material, commonly clay and silt, from the formation near the borehole. This is accomplished by pumping or bailing water from the well. However, particles moving toward the borehole tend to "bridge" and form blockages that restrict subsequent particulate movement. Flow reversals will generally remove such bridges and allow the continued movement of particulates toward the well for subsequent removal. Flow reversals can be induced by a surge block, bailers, or backwashing through a pump.

Methods that involve the use of air can potentially alter ground water quality. Therefore, jetting, airlift pumping, and air surging are not recommended for

development of monitoring wells. The addition of water to a well is also undesirable because it will alter ground water quality and increase development time. However, site-specific applications of these methods may be permitted if geological conditions warrant. Consult the EPA Region VIII Field Quality Assurance Officer (FQAO), the Superfund Hydrogeologist, or the Regional QAO for approval.

During development, certain well and formation characteristics must be noted and evaluated to provide later guidance for well purging and sample collection. Recommended well purging procedures (given in the EPA Region VIII Well Purging SOP) require a pumping rate that is at or below the well recovery rate. The well recovery rate can be estimated during development. The discharge rate during development must exceed the pumping rate that will be used to purge wells prior to sample collection. However, high-volume pumping can result in dewatering a well, and can cause the collapse of the well screen. If a well is dewatered during development, the well should be allowed to recover before development resumes to ensure development throughout the saturated interval.

If water was added during well construction or development, two to three times the volume of water added should be removed. The quality of any water added to the well must be documented by analytical testing, and caution should be taken to prevent the added water from degrading the formation water quality.

The most generally applicable development procedures include:

- 1) surging;
- 2) bailing;
- 3) pumping, overpumping, and backwashing through a pump; and
- 4) combinations of these methods.

The first three development methods are each described in a section below.

3.3.1 Surging

Well surging is most effectively accomplished by using a surge block. Surge blocks are operated by a pumping action (e.g., strokes of approximately three feet up and down). The pumping action causes flow reversals and pulls the fines into the well. The surge block is periodically removed and the accumulated fines are removed by pumping or bailing. Surging is started at the top of the screened interval so that material loosened will not cascade on top of the surge block and prevent the removal of the surge block from the well. Surging should initially be gentle and gradually increase in intensity during the development process.

Caution is advised, because surging too vigorously can result in the collapse of the well casing or screen. The steps in the surge block development process are as follows:

- 1) Initially operate the surge block with short gentle strokes above the well intake;
- 2) Alternate surging with removal of accumulated fines by pumping or bailing;
- 3) Gradually increase surging energy at each depth until no sediment is produced from that depth;
- 4) Increase the depth of surging in small increments from the top to bottom of the screened interval; and
- 5) Repeat the four-step process as necessary until the entire interval has been developed and the development acceptance criteria described in Section 3.2 are achieved.

3.3.2 Bailing

Bailing can be used to develop wells. Bailers can function as a surge block by creating flow reversals, but are not as efficient at creating flow reversals as surge blocks. Bailer operation should follow the same general development procedure specified for surge blocks in Section 3.3.1. The bailer development steps are summarized as follows:

- 1) Initially drop the bailer into the water in the well casing, and lower to a depth at the top of the screened interval. Pull up from the water and re-drop to the same depth several times;
- 2) Remove the bailer from the well periodically to recover the fine sediments that accumulate in the bailer;
- 3) Repeat steps 1 and 2 until no sediment is recovered in the bailer;
- 4) Increase the depth of development by dropping the bailer to a lower depth along the screened interval. Periodically remove the bailer from the well to recover sediments; and
- 5) Repeat the process as necessary until the entire interval has been developed and the development acceptance criteria described in Section 3.2 are achieved.

3.3.3 Pumping, Overpumping, and Backwashing

A combination of pumping, overpumping, and backwashing through a pump is commonly used to develop wells. The pump check valve must be open or removed to allow water to backflow into the well when the pump is turned off. Flow reversal through the screen can be accomplished by starting and stopping the pump and allowing water in the discharge hose to backflow into the well. The development procedure for pumping, overpumping and backwashing should follow the same general steps outlined for surging and bailing as follows:

- 1) Begin pumping at the top of the screened interval; with a low pumping rate. Shut off the pump and allow the water to backwash into the well and through the screen;
- 2) Gradually increase pumping rate and development energy and alternate with periodic backwashing until no fine sediments are produced from that interval;
- 3) Increase the depth of pumping and backwashing in increments from the top to bottom of the screened interval, repeating steps 1 and 2 at each depth; and
- 4) Repeat the process as necessary until the entire interval has been developed and the development acceptance criteria described in Section 3.2 are achieved.

3.4 Development of Low-Yield Wells

Wells installed in low-yielding formations are difficult to develop and the development methods discussed above may not be effective. At times there may be no other option but to follow the procedures presented above, allowing the well to recover between efforts. This development procedure may take many days and considerable effort, but it may be required to produce representative samples. Water may sometimes be added to wells during development to improve yield. The addition of water to facilitate development is recommended only if all other procedures fail. Regional EPA staff must be consulted before this action. Another possible procedure is to circulate clean water down the well casing and back up through the annulus after placement of the sand pack, but before installation of the annular seal. Because of the low hydraulic conductivity of such formations, a negligible amount of water will penetrate the formation. Immediately following the procedure, the annular seal should be installed. After the seal has set, the well should be pumped to remove as much of the water used in the development process as possible.

3.5 General Development Considerations

During well construction, debris can accumulate on the casing above the normal water level. The inside of the well casing should be rinsed with clean formation water during development. Rinsing the well casing should be performed early in the development procedure and periodically thereafter to ensure that debris washed down the well casing will be removed during development.

The water level and well depth must be measured both before and after development. Well depth measurements are made to determine the presence or absence of sediment in the well, and to allow calculation of casing volume. Accumulated sediments should be removed during the development procedure. Water-level measurements are used to calculate the casing volume (to allow evaluation of the stability of field parameters). Final water-level and well depth measurements should be collected after the well has fully recovered.

3.5.1 Equipment Decontamination and Waste Disposal

All development equipment must be properly decontaminated before use. The Region VIII Standard Operating Procedures for Field Sampling Activities document addresses appropriate procedures for decontamination of drilling and sampling equipment. The development equipment must be placed on plastic sheeting or a similar material to prevent contamination of the surface soils and the development equipment.

Disposal of development fluids must be addressed before development begins. Depending on site-specific conditions, development fluids generally are containerized and tested to determine proper disposal. Contaminated ground water must be disposed of properly, as specified in the approved sampling plan. See the Region VIII Standard Operating Procedures for Field Sampling Activities document for more information on handling investigation-derived waste.

3.5.2 Timing for Development After Well Construction

Development should normally not begin until the annular seal has set and hardened, a minimum of 24 hours. Ideally, the protective casing, the cement surface pad, and protective posts should also be installed before development begins. After development is completed, wells should be allowed to stabilize and re-equilibrate for several days to several weeks before sampling is begun. In higher-permeability formations such as karst or clean gravel facies, shorter re-equilibration time frames may be appropriate. Generally, high-permeability formations require less time to equilibrate than low-permeability formations.

In some cases, pre-development of a well may be beneficial. Pre-development consists of pumping the well after installation of the sand pack, but before installation of the annular seal. This procedure is effective when thick drilling fluids in the borehole cannot be purged before well construction for fear of collapsing the borehole. Pre-development will ensure that the sand pack is completely settled and facilitates removal of the drilling fluids. However, development should never be conducted after the annular seal has been placed but before the seal been allowed to set completely.

4.0 DOCUMENTATION AND FIELD FORMS

All monitor well development data must be recorded in a bound, sequentially numbered field log book or on a data sheet that is referenced in the field log book. The field log book or data sheet must contain a complete record of all equipment used, activities conducted, measurements of field parameters, casing volume calculations, and observations. The information recorded must be sufficient to allow the reconstruction and evaluation of the adequacy of the development procedure. The data recorded must also allow calculation of a recommended purge rate, and must indicate if the turbidity goal of 5 NTU cannot be achieved, and why. Field notes should also include explanations of problems encountered during well development and an explanation of any trouble-shooting techniques used. If a separate data sheet or field form is used, it should be designed with prompts for all of the required data. In particular, the following must be included:

- 1) Date and duration of development.
- 2) Depth to water from the marked measuring point on the top of casing before development and after recovery, if possible.
- 3) Depth from top of well casing to the top of any sediment present in the well, before, during, and after development.
- 4) The value used for one casing volume, calculated from the well diameter and the total length of the water column in the well (total depth minus depth to water).
- 5) Types and quantities of drilling fluids or development water introduced during drilling and development.
- 6) Field measurements of pH, specific conductance, temperature and turbidity taken before, during and after well development. Measurements taken must be recorded after each 1/2 casing volume is removed.
- 7) Total volume and physical characteristics of developed water (e.g., odor, color, clarity, particulate matter).
- 8) Complete description of equipment used for development, including type and capacity of pump and/or bailer used and minimum and maximum pumping rates used.
- 9) Name and affiliation of person(s) conducting development, and any observers on site.
- 10) The field parameter measurements for the final casing volume, especially for turbidity. If the goal of 5 NTU was not met, these final measurements must reflect stabilization within 20%.

5.0 REGION VIII CONTACT NAMES AND PHONE NUMBERS

The individuals identified in the positions listed below can be contacted for advice on acceptable turbidity and other development parameters. This list will be updated as needed, to reflect changes in personnel or telephone numbers.

Regional Quality Assurance Officer:	Richard Lynn Edmonds	(303) 293-0996
Field Quality Assurance Officer:	Lynnette A. Gandl	(303) 293-0993
Superfund Hydrogeologist: (Superfund only)	Darcy J. Campbell	(303) 294-7596

GLOSSARY

BACKWASHING	The surging effect or reversal of water flow in well that removes fine-grained material from the formation surrounding the borehole. Only formation water is used during this process.
JETTING	Bursts of high-pressure water injected into the well.
OVERPUMPING	Pumping at rates generally greater than those used during sampling or well purging. Commonly combined with surging of the well.
SURGE BLOCK	A plunger-like tool, consisting of leather or rubber discs sandwiched between steel or wooden discs that may be solid or valved, that is used in well development.
SURGING	A well development technique where the surge block is alternatively lifted and dropped within the borehole above or adjacent to the screen to create a strong inward and outward movement of water through the well intake.
TURBIDITY	Solids and natural organic matter suspended in water.

ACRONYMS

FSP	Field Sampling Plan
NTU	nephelometric turbidity units
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure

REFERENCES

Aller, L., et al. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. EPA/600/4-89/034. Published in NWWA/EPA series by National Water Well Association, Dublin, OH.

Aller, L., et al. 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Published in NWWA/EPA series by National Water Well Association, Dublin, OH.

ASTM 5092-90, American Society of Testing and Materials, "Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers"

ASTM D:1889, American Society of Testing and Materials, "Standard Test Method for Turbidity of Water"

Barcelona, M.J., et al. 1985. Practical Guide For Ground-Water Sampling. EPA/600/2-85/104. Published with EPA/Illinois State Water Survey DOE and Natural Resources, Champaign, IL.

Driscoll, F.G., 1986, Groundwater and Wells, Johnson Division, St. Paul, MN

Gibb, James P., Schuller, R.M. and Griffin, R.A., 1981, "Procedures for the Collection of Representative Water Quality Data from Monitoring Wells," Illinois State Water Survey, Cooperative Groundwater Report 7, Champaign, IL. 61 p.

U.S. Environmental Protection Agency, 1986, Office of Waste Program Enforcement, Office of Solid Waste and Emergency Response, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, September 1986.

U.S. Environmental Protection Agency, 1992, Office of Solid Waste and Emergency Response, Monitoring Well Development Guidelines for Superfund Project Managers, Ground Water Forum Issue Paper, April 1992.

U.S. Environmental Protection Agency, 1994, Region VIII Standard Operating Procedures for Field Sampling Activities.

U.S. Environmental Protection Agency, 1992, Office of Solid Waste, RCRA Ground-Water Monitoring, Draft Technical Guidance, November 1992.

APPENDIX C

**TETRA TECH SOP – WATER LEVEL, IMMISCIBLE
LAYER, AND WELL DEPTH MEASUREMENT**

TETRA TECH

STANDARD OPERATING PROCEDURE No. 11

WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed during measurement of water levels, immiscible layer levels and depths of monitoring wells and piezometers. The procedures presented herein are intended to be general in nature and, as the work progresses and when warranted, appropriate revisions may be made when approved in writing by the Tetra Tech Project Manager.

2.0 PROCEDURES

Prior to performing water level, immiscible layer and well depth measurements, the construction details and previous measurements for each well or piezometer shall be reviewed by the Tetra Tech field geologist so any anomalous measurements may be identified. Well construction details and previous measurements shall be available in the field for review.

In general, water-level and immiscible-layer depth measurements shall be performed before groundwater is removed from the well by purging or sampling.

2.1 Equipment

Equipment that may be necessary to perform measurements (depending on measurements to be performed):

- Well/piezometer construction details
- Water-level meter
- Water Level Monitoring Record Sheet
- Interface probe/gas-finding paste/water-finding paste
- Weighted steel surveyor's tape measuring to the nearest 1/10 foot.

2.2 Measuring Point

A measuring point (MP) shall be selected and marked for each monitoring well and piezometer in which water level measurements will be made. Generally, the MP will be the top of the well casing on the north side. The MP will be permanently marked using an indelible marker or a notch cut into the PVC casing. When the top-of-casing elevation of a monitoring well or piezometer is surveyed, the licensed surveyor shall measure the MP elevation and reference this measurement to an appropriate datum (such as feet above mean sea level).

2.3 Water Level Measurements

When water levels are measured to describe the groundwater potentiometric surface, the water level will be measured prior to purging. All water level measurements will be recorded to the nearest hundredth of one foot. Note the instrument used for each measurement on the Water Level Monitoring Record (Figure SOP-11-1). The measurement procedures to be followed when an immiscible layer is present or suspected in a well are discussed in Section 2.3. Water levels are measured using the electric probe method, as discussed below.

An electric probe consists of a contact electrode attached to the end of an insulated electric cable, and a reel which houses an ammeter, a buzzer, or other closed circuit indicator. The indicator shows a closed circuit and flow of current when the electrode touches the water surface. The electric probes used shall be calibrated periodically by comparing the depth-to-water readings between the electric probe and a steel surveyors' tape. Calibration procedures are discussed in Part B of this section.

The procedure for measuring water levels with an electric probe is as follows:

1. Switch on.
2. Lower the electric cable into the well until the ammeter or buzzer indicates a closed circuit. Raise and lower the electric cable slightly until the shortest length of cable that gives the maximum response on the indicator is found.
3. With the cable in this fixed position, note the depth to water from the Measuring Point (MP).
4. Repeat as necessary until at least two identical duplicate measurements are obtained.

Calibration of the electric probe will be checked at regular intervals as part of regular maintenance measuring the position of the electrode to check that the calibration marks on the electric probe correspond to those on the steel surveyors tape.

2.4 Immiscible Layer Measurement and Sampling

2.4.1 Immiscible Layer Measurement

The thickness of non-aqueous phase liquid (NAPL) in a well may be measured by using (A) an interface probe, (B) gas-finding paste with a water-level meter or (C) water-finding paste with a steel surveyor's tape.

- A. Use an interface probe in a similar fashion as an electric water-level probe. An interface probe may be used to measure the thickness of both a light-phase NAPL (LNAPL) and a dense-phase NAPL (sinker). Measure a light-phase NAPL prior to measuring a dense-phase NAPL.
- B. Gasoline gauging paste is used for measuring LNAPL (floaters) only. Gasoline gauging paste can be used to detect petroleum hydrocarbons and other LNAPL chemicals. Using a graduated electronic water-level probe, apply a thin layer of gasoline gauging paste (Kolor-kut brand or equivalent) to the amount of tape greater than the anticipated LNAPL thickness. Make a depth to water measurement; probe buzzer/light will activate when it contacts the water (not the LNAPL). Record the depth to water from the MP then quickly reel up the tape. Record level of the LNAPL on the tape by noting where the gasoline gauging paste has changed color. This level will be the thickness of the LNAPL layer.
- C. Water-finding paste is used only for LNAPLs. Using a steel surveyor's tape coated with chalk on the bottom foot, take a depth to "liquid" measurement from the measuring point (MP) of the well, as described in Section 2.2. Record the depth to "liquid" measurement. Clean and dry the steel tape and recoat the bottom calibrated foot with fresh chalk. Along one edge of the bottom calibrated foot of the steel tape, apply a thin layer of the yellow water-finding paste (Kolor-Kut brand or equivalent). Take another "depth to liquid" measurement from the MP of the well. Upon retrieving the steel tape, quickly note the depth to "liquid" marked by the wet/dry chalk interface along one edge, and the depth to water marked by the yellow/red paste interface along the other edge. Record the chalk measurement as the depth to "liquid" and the paste measurement as the depth to water. The thickness of the NAPL is the difference between these two measurements. If the two readings are identical, then there is no measurable NAPL in the well.

Record the thickness of the NAPL in the "Remarks" column of the Water Level Monitoring Record (Figure SOP-11-1). To calculate the corrected water level elevation in the presence of LNAPL, use the worksheet provided as Figure SOP-11-2.

If a light-phase NAPL (floaters) is not detected using the water-finding paste, gasoline gauging paste or interface probe, but the presence of light-phase NAPL is suspected, the presence of a very thin layer or sheen (too thin to be measured) may also be checked using a bottom-filling transparent bailer. The presence of a light-phase layer is checked by lowering the bailer into the well. Care must be taken to not completely submerge the bailer. Retrieve the bailer and visually examine the air/liquid interface for the presence of an immiscible light-phase layer or sheen. Note that the transparent bailer is not to be used to measure the thickness of light-phase NAPL in a well.

The presence of a dense-phase NAPL (sinker) may also be checked next by lowering the bailer to the base of the well. Retrieve the bailer and visually examine for the presence of an immiscible, dense-phase layer. Note that the transparent bailer is not to be used to measure the thickness of dense-phase NAPL in a well.

2.4.2 Immiscible Layer Sampling

Samples of immiscible layers may be obtained with a bailer (A) or a peristaltic pump (B), if the well is shallow (i.e., depths of about 20 feet or less, depending upon the liquid).

- A. Bailer Method -- A appropriate sampling bailer with a ball check valve is submerged to the desired sample depth, either directly or by suspending the bailer on a rope from a pole.
- B. Peristaltic Pump Method -- The sample is collected through a section of clean, flexible Tygon (polyvinyl chloride) tubing which will not be reused. The tubing intake will be secured manually or by attaching weights. This procedure may be modified to collect the sample through a Teflon tube into a sample flask by running the pump on a vacuum.

Sample containers prepared specifically for the required analyses by the analytical laboratory or their supplier will be used for sample collection. To collect a sample in a volatile organic analysis (VOA) vial, remove the cap with Teflon-lined septum, then fill slowly (avoiding agitation) until a meniscus of NAPL (held by surface tension) extends above the top of the vial. Carefully replace the cap, then turn the vial upside down and tap gently while checking to ensure that no headspace (air bubbles) is present in the vial.

2.4.3 Sample Handling

Care should be taken to thoroughly clean the outside of the sample bottles that contain the immiscible liquids. To avoid potential cross-contamination, these samples will be kept in a designated ice chest, separate from other groundwater samples. Equipment used in immiscible layer measurement and sampling must be thoroughly decontaminated in accordance with the procedure described in Section 4.0 of this SOP. Samples will be handled in accordance with the procedures described in the MFG SOP entitled SAMPLE CUSTODY.

2.5 Well Depth Measurements

The total depth of a well shall be measured by sounding with a weighted steel surveyors' tape or other steel or fiberglass measuring tape, weighted as needed. For shallow wells, the electronic water-level probe may also be used as a measuring device. Procedures to be followed are specified below.

- A. For calibration, measure the distance between the zero mark on the end of the measuring tape and the bottom of the weight to the nearest 1/10 foot at the beginning of each well depth measurement activity day, and whenever the apparatus is altered.
- B. Lower a weighted tape into the well until the tape becomes slack or there is a noticeable decrease in weight, which indicates the bottom of the well. Care should be taken to lower the tape slowly to avoid damage to the bottom of the well by the weight. Raise the tape slowly until it just becomes taut, and with the tape in this fixed position, note the tape reading opposite the Measuring Point to the nearest 1/10 foot. Add the values from the distance from the end of the tape to the end of the weight together, round this number to nearest 1/10 foot, and record the resulting value as "well depth below MP" in the "Remarks" column of the Water Level Monitoring Record form.

2.6 DOCUMENTATION AND RECORDS MANAGEMENT

Water levels observed in wells selected for the groundwater level monitoring program will be tabulated on a Water Level Monitoring Record form during each monitoring period (Figure SOP-11-1). The date and time of each measurement will also be recorded on the Water Level Monitoring Record. All water level measurements shall be recorded to the nearest 1/100 foot, and all depth measurements shall be noted to the nearest 1/10 foot.

Water level data will be recorded as feet below measuring point so that water level elevations may be calculated from the depth-to-water measurement (from measuring point) and the surveyed elevation of the measuring point at each well or piezometer.

Well depth measurements may be recorded in the "Remarks" column of the Water Level Monitoring Record.

If free product is encountered during water level measurement, the measured thickness or observation shall be recorded in the "Remarks" column. Each form or, as appropriate, individual measurement data, shall be signed to indicate the originator. If LNAPL is encountered, the corrected water level elevation may be calculated using the procedures included on Figure SOP-11-2.

3.0 QUALITY CONTROL

3.1 Equipment Decontamination/Cleaning

Steel surveyors' tapes, electric well probes, and other measuring tapes shall be cleaned prior to use and after measurements in each well are completed. Cleaning shall be accomplished by either (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, then rinsing with distilled or deionized water, or (2) steam cleaning followed by rinsing with distilled or deionized water. An acid rinse (0.1 N HCl) or solvent rinse (i.e., hexane or methanol) may be used to supplement these cleaning steps if tarry or oily deposits are encountered. The acid or solvent rinse will be followed by thoroughly rinsing with municipal water and then with distilled or deionized water. After cleaning, equipment will be packaged and sealed in plastic bags or other appropriate containers to minimize contact with dust or other contaminants.

3.2 Technical and Records Reviews

The project manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

In addition, all calculations of water-level elevations and NAPL correction to water-level elevations must be reviewed before they are submitted to the project file and used to describe site conditions. The calculation review should be performed by technical personnel familiar with this procedure. Evidence of the completed review and any necessary corrections to calculations should also be submitted to the project file.

APPENDIX D

EPA ERT SOP NUMBER 2007 – GROUNDWATER WELL SAMPLING

PB91-921275

OSWER Directive 9360.4-06
January 1991

COMPENDIUM OF ERT GROUNDWATER SAMPLING PROCEDURES

Sampling Equipment Decontamination

* Groundwater Well Sampling

Soil Gas Sampling

Monitoring Well Installation

Water Level Measurement

Well Development

Controlled Pumping Test

Slug Test

Interim Final

Environmental Response Team
Emergency Response Division

Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, DC 20460

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2.0 GROUNDWATER WELL SAMPLING: SOP #2007

2.1 SCOPE AND APPLICATION

The objective of this Standard Operating Procedure (SOP) is to provide general reference information on sampling of groundwater wells. This guideline is primarily concerned with the collection of water samples from the saturated zone of the subsurface. Every effort must be made to ensure that the sample is representative of the particular zone of water being sampled. These procedures are designed to be used in conjunction with analyses for the most common types of groundwater contaminants (e.g., volatile and semi-volatile organic compounds, pesticides, metals, biological parameters).

2.2 METHOD SUMMARY

Prior to sampling a monitoring well, the well must be purged. This may be done with a number of instruments. The most common of these are the bailer, submersible pump, non-gas contact bladder pump and inertia pump. At a minimum, three well volumes should be purged, if possible. Equipment must be decontaminated prior to use and between wells. Once purging is completed and the correct laboratory-cleaned sample containers have been prepared, sampling may proceed. Sampling may be conducted with any of the above instruments, and need not be the same as the device used for purging. Care should be taken when choosing the sampling device as some will affect the integrity of the sample. Sampling equipment must also be decontaminated. Sampling should occur in a progression from the least to most contaminated well, if this information is known.

2.3 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The type of analysis for which a sample is being collected determines the type of bottle, preservative, holding time, and filtering requirements. Samples should be collected directly from the sampling device into appropriate laboratory-cleaned containers. Check that a Teflon liner is present in

the cap, if required. Attach a sample identification label. Complete a field data sheet, a chain of custody form and record all pertinent data in the site logbook.

Samples shall be appropriately preserved, labelled, logged, and placed in a cooler to be maintained at 4°C. Samples must be shipped well before the holding time is over and ideally should be shipped within 24 hours of sample collection. It is imperative that these samples be shipped or delivered daily to the analytical laboratory in order to maximize the time available for the laboratory to perform the analysis. The bottles should be shipped with adequate packing and cooling to ensure that they arrive intact.

Certain conditions may require special handling techniques. For example, treatment of a sample for volatile organic (VOA) analysis with sodium thiosulfate preservative is required if there is residual chlorine in the water (such as public water supply) that could cause free radical chlorination and change the identity of the original contaminants. However, sodium thiosulfate should not be used if chlorine is not present in the water. Special requirements must be determined prior to conducting fieldwork.

2.4 INTERFERENCES AND POTENTIAL PROBLEMS

2.4.1 General

The primary goal of groundwater sampling is to obtain a representative sample of the groundwater body. Analysis can be compromised by field personnel in two primary ways: (1) taking an unrepresentative sample, or (2) by incorrect handling of the sample. There are numerous ways of introducing foreign contaminants into a sample, and these must be avoided by following strict sampling procedures and only utilizing trained field personnel.

2.4.2 Purging

In a non-pumping well, there will be little or no vertical mixing of the water, and stratification will

occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated, become stagnant and lack the VOAs representative of the groundwater. Sampling personnel should realize that stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in an unrepresentative sample. To safeguard against collecting nonrepresentative stagnant water, follow these guidelines during sampling:

- As a general rule, all monitoring wells should be pumped or bailed prior to sampling. Purge water should be containerized on site or handled as specified in the site-specific project plan. Evacuation of a minimum of one volume of water in the well casing, and preferably three to five volumes, is recommended for a representative sample. In a high-yielding ground water formation and where there is no stagnant water in the well above the screened section, evacuation prior to sample withdrawal is not as critical. However, in all cases where the monitoring data is to be used for enforcement actions, evacuation is recommended.
- For wells that can be pumped or bailed to dryness with the equipment being used, the well should be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and the schedule allows, evacuation of more than one volume of water is preferred. If recovery is slow, sample the well upon recovery after one evacuation.
- A nonrepresentative sample can also result from excessive pre-pumping of the monitoring well. Stratification of the leachate concentration in the groundwater formation may occur, or heavier-than-water compounds may sink to the lower portions of the aquifer. Excessive pumping can dilute or increase the contaminant concentrations from what is representative of the sampling point of interest.

2.4.3 Materials

Samplers and evacuation equipment (bladders, pumps, bailers, tubing, etc.) should be limited to

those made with stainless steel, Teflon, and glass in areas where concentrations are expected to be at or near the detection limit. The tendency of organics to leach into and out of many materials make the selection of materials critical for trace analyses. The use of plastics, such as PVC or polyethylene, should be avoided when analyzing for organics. However, PVC may be used for evacuation equipment as it will not come in contact with the sample.

Table 2 on page 7 discusses the advantages and disadvantages of certain equipment.

2.5 EQUIPMENT/APPARATUS

2.5.1 General

- water level indicator
 - electric sounder
 - steel tape
 - transducer
 - reflection sounder
 - airline
- depth sounder
- appropriate keys for well cap locks
- steel brush
- HNU or OVA (whichever is most appropriate)
- logbook
- calculator
- field data sheets
- chain of custody forms
- forms and seals
- sample containers
- Engineer's rule
- sharp knife (locking blade)
- tool box (to include at least: screwdrivers, pliers, hacksaw, hammer, flashlight, adjustable wrench)
- leather work gloves
- appropriate health and safety gear
- 5-gallon pail
- plastic sheeting
- shipping containers
- packing materials
- bolt cutters
- Ziploc plastic bags
- containers for evacuation of liquids
- decontamination solutions
- tap water
- non-phosphate soap
- several brushes

**Table 2: Advantages and Disadvantages
of Various Groundwater Sampling Devices**

Device	Advantages	Disadvantages
Bailer	<ul style="list-style-type: none"> • The only practical limitations are size and materials • No power source needed • Portable • Inexpensive; it can be dedicated and hung in a well reducing the chances of cross-contamination • Minimal outgassing of volatile organics while sample is in bailer • Readily available • Removes stagnant water first • Rapid, simple method for removing small volumes of purge water 	<ul style="list-style-type: none"> • Time consuming, especially for large wells • Transfer of sample may cause aeration
Submersible Pump	<ul style="list-style-type: none"> • Portable; can be used on an unlimited number of wells • Relatively high pumping rate (dependent on depth and size of pump) • Generally very reliable; does not require priming 	<ul style="list-style-type: none"> • Potential for effects on analysis of trace organics • Heavy and cumbersome, particularly in deeper wells • Expensive • Power source needed • Susceptible to damage from silt or sediment • Impractical in low yielding or shallow wells
Non-Gas Contact Bladder Pump	<ul style="list-style-type: none"> • Maintains integrity of sample • Easy to use 	<ul style="list-style-type: none"> • Difficult to clean although dedicated tubing and bladder may be used • Only useful to approximately 100 feet in depth • Supply of gas for operation (bottled gas and/or compressor) is difficult to obtain and is cumbersome
Suction Pump	<ul style="list-style-type: none"> • Portable, inexpensive, and readily available 	<ul style="list-style-type: none"> • Only useful to approximately 25 feet or less in depth • Vacuum can cause loss of dissolved gases and volatile organics • Pump must be primed and vacuum is often difficult to maintain • May cause pH modification
Inertia Pump	<ul style="list-style-type: none"> • Portable, inexpensive, and readily available • Rapid method for purging relatively shallow wells 	<ul style="list-style-type: none"> • Only useful to approximately 70 feet or less in depth • May be time consuming to use • Labor intensive • WaTerra pump is only effective in 2-inch diameter wells

- pails or tubs
- aluminum foil
- garden sprayer
- preservatives
- distilled or deionized water

2.5.2 Bailer

- clean, decontaminated bailer(s) of appropriate size and construction material
- nylon line, enough to dedicate to each well
- Teflon-coated bailer wire
- sharp knife
- aluminum foil (to wrap clean bailers)
- 5-gallon bucket

2.5.3 Submersible Pump

- pump(s)
- generator (110, 120, or 240 volt) or 12-volt battery if inaccessible to field vehicle
- 1-inch black PVC coil pipe -- enough to dedicate to each well
- hose clamps
- safety cable
- tool box supplement
 - pipe wrenches, 2
 - wire strippers
 - electrical tape
 - heat shrink
 - hose connectors
 - Teflon tape
- winch or pulley
- gasoline for generator
- flow meter with gate valve
- 1-inch nipples and various plumbing (i.e., pipe connectors)

2.5.4 Non-Gas Contact Bladder Pump

- non-gas contact bladder pump
- compressor or nitrogen gas tank
- batteries and charger
- Teflon tubing -- enough to dedicate to each well
- Swagelok fitting
- toolbox supplements -- same as submersible pump

2.5.5 Suction Pump

- pump
- black coil tubing -- enough to dedicate to each well

- gasoline -- if required
- toolbox
- plumbing fittings
- flow meter with gate valve

2.5.6 Inertia Pump

- pump assembly (WaTerra pump, piston pump)
- 5-gallon bucket

2.6 REAGENTS

Reagents will be utilized for preservation of samples and for decontamination of sampling equipment. The preservation required is specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

2.7 PROCEDURES

2.7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies are needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or preclean equipment, and ensure that it is in working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site-specific health and safety plan.
6. Identify and mark all sampling locations.

2.7.2 Field Preparation

1. Start at the least contaminated well, if known.
2. Lay plastic sheeting around the well to minimize likelihood of contamination of equipment from soil adjacent to the well.

3. Remove locking well cap, note location, time of day, and date in field notebook or an appropriate log form.
4. Remove well casing cap.
5. Screen headspace of well with an appropriate monitoring instrument to determine the presence of volatile organic compounds and record in site logbook.
6. Lower water level measuring device or equivalent (i.e., permanently installed transducers or airline) into well until water surface is encountered.
7. Measure distance from water surface to reference measuring point on well casing or protective barrier post and record in site logbook. Alternatively, if there is no reference point, note that water level measurement is from top of steel casing, top of PVC riser pipe, from ground surface, or some other position on the well head.
8. Measure total depth of well (do this at least twice to confirm measurement) and record in site logbook or on log form.
9. Calculate the volume of water in the well and the volume to be purged using the calculations in Section 2.8.
10. Select the appropriate purging and sampling equipment.

2.7.3 Evacuation of Static Water (Purging)

The amount of flushing a well receives prior to sample collection depends on the intent of the monitoring program as well as the hydrogeologic conditions. Programs where overall quality determination of water resources are involved may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume can be determined prior to sampling so that the sample is a composite of known volume of the aquifer, or the well can be pumped until the stabilization of parameters such as temperature, electrical conductance, or pH has occurred.

However, monitoring for defining a contaminant plume requires a representative sample of a small volume of the aquifer. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce flow from other areas. Generally, three well volumes are considered effective, or calculations can be made to determine, on the basis of the aquifer parameters and well dimensions, the appropriate volume to remove prior to sampling.

During purging, water level measurements may be taken regularly at 15- to 30-second intervals. This data may be used to compute aquifer transmissivity and other hydraulic characteristics.

The following well evacuation devices are most commonly used. Other evacuation devices are available, but have been omitted in this discussion due to their limited use.

Bailer

Bailers are the simplest purging device used and have many advantages. They generally consist of a rigid length of tube, usually with a ball check-valve at the bottom. A line is used to lower the bailer into the well and retrieve a volume of water. The three most common types of bailer are PVC, Teflon, and stainless steel.

This manual method of purging is best suited to shallow or narrow diameter wells. For deep, larger diameter wells which require evacuation of large volumes of water, other mechanical devices may be more appropriate.

Bailing equipment includes a clean decontaminated bailer, Teflon or nylon line, a sharp knife, and plastic sheeting.

1. Determine the volume of water to be purged as described in Section 2.7.2, Field Preparation.
2. Lay plastic sheeting around the well to prevent contamination of the bailer line with foreign materials.
3. Attach the line to the bailer and lower until the bailer is completely submerged.
4. Pull bailer out ensuring that the line either falls onto a clean area of plastic sheeting or never touches the ground.

5. Empty the bailer into a pail until full to determine the number of bails necessary to achieve the required purge volume.
6. Thereafter, pour the water into a container and dispose of purge waters as specified in the site-specific project plan.

Submersible Pump

Submersible pumps are generally constructed of plastic, rubber, and metal parts which may affect the analysis of samples for certain trace organics and inorganics. As a consequence, submersible pumps may not be appropriate for investigations requiring analyses of samples for trace contaminants. However, they are still useful for pre-sample purging. However, the pump must have a check valve to prevent water in the pump and the pipe from rushing back into the well.

Submersible pumps generally use one of two types of power supplies, either electric or compressed gas. Electric pumps can be powered by a 12-volt DC rechargeable battery, or a 110- or 220-volt AC power supply. Those units powered by compressed gas normally use a small electric compressor which also needs 12-volt DC or 110-volt AC power. They may also utilize compressed gas from bottles. Pumps differ according to the depth and diameter of the monitoring wells.

1. Determine the volume of water to be purged as described in section 2.7.2, Field Preparation.
2. Lay plastic sheeting around the well to prevent contamination of pumps, hoses or lines with foreign materials.
3. Assemble pump, hoses and safety cable, and lower the pump into the well. Make sure the pump is deep enough so that purging does not evacuate all the water. (Running the pump without water may cause damage.)
4. Attach flow meter to the outlet hose to measure the volume of water purged.
5. Attach power supply, and purge well until specified volume of water has been evacuated (or until field parameters, such as temperature, pH, conductivity, etc. have stabilized). Do not allow the pump to run dry. If the pumping rate

exceeds the well recharge rate, lower the pump further into the well, and continue pumping.

6. Collect and dispose of purge waters as specified in the site-specific project plan.

Non-Contact Gas Bladder Pump

For this procedure, an all stainless-steel and Teflon Middleburg-squeeze bladder pump (e.g., IEA, TIMCO, Well Wizard, Geoguard, and others) is used to provide the least amount of material interference to the sample (Barcelona, 1985). Water comes into contact with the inside of the bladder (Teflon) and the sample tubing, also Teflon, that may be dedicated to each well. Some wells may have permanently installed bladder pumps (i.e., Well Wizard, Geoguard), that will be used to sample for all parameters.

1. Assemble Teflon tubing, pump and charged control box.
2. Use the same procedure for purging with a bladder pump as for a submersible pump.
3. Be sure to adjust flow rate to prevent violent jolting of the hose as sample is drawn in.

Suction Pump

There are many different types of suction pumps. They include: centrifugal, peristaltic and diaphragm. Diaphragm pumps can be used for well evacuation at a fast pumping rate and sampling at a low pumping rate. The peristaltic pump is a low-volume pump that uses rollers to squeeze the flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross-contamination. Peristaltic pumps, however, require a power source.

1. Assemble the pump, tubing, and power source if necessary.
2. To purge with a suction pump, follow the exact procedures outlined for the submersible pump.

Inertia Pump

Inertia pumps, such as the WaTerra pump and piston pump, are manually operated. They are appropriate to use when wells are too deep to bail by hand, but are not inaccessible enough to warrant an automatic (submersible, etc.) pump. These

pumps are made of plastic and may be either decontaminated or discarded, after use.

1. Determine the volume of water to be purged as described in Section 2.7.2, Field Preparation.
2. Lay plastic sheeting around the well to prevent contamination of pumps or hoses with foreign materials.
3. Assemble pump, and lower to the appropriate depth in the well.
4. Begin pumping manually, discharging water into a 5-gallon bucket (or other graduated vessel). Purge until specified volume of water has been evacuated (or until field parameters such as temperature, pH, conductivity, etc. have stabilized).
5. Collect and dispose of purge waters as specified in the site-specific project plan.

2.7.4 Sampling

Sample withdrawal methods require the use of pumps, compressed air, bailers, and samplers. Ideally, purging and sample withdrawal equipment should be completely inert, economical to use, easily cleaned, sterilized, reusable, able to operate at remote sites in the absence of power resources, and capable of delivering variable rates for sample collection.

There are several factors to take into consideration when choosing a sampling device. Care should be taken when reviewing the advantages or disadvantages of any one device. It may be appropriate to use a different device to sample than that which was used to purge. The most common example of this is the use of a submersible pump to purge and a bailer to sample.

Bailer

The positive-displacement volatile sampling bailer (by GPI) is perhaps the most appropriate for collection of water samples for volatile analysis. Other bailer types (messenger, bottom fill, etc.) are less desirable, but may be mandated by cost and site conditions. Generally, bailers can provide an acceptable sample, providing that sampling personnel use extra care in the collection process.

1. Surround the monitoring well with clean plastic sheeting.
2. Attach a line to the bailer. If a bailer was used for purging, the same bailer and line may be used for sampling.
3. Lower the bailer slowly and gently into the well, taking care not to shake the casing sides or to splash the bailer into the water. Stop lowering at a point adjacent to the screen.
4. Allow bailer to fill and then slowly and gently retrieve the bailer from the well, avoiding contact with the casing, so as not to knock flakes of rust or other foreign materials into the bailer.
5. Remove the cap from the sample container and place it on the plastic sheet or in a location where it will not become contaminated. See Section 2.7.7 for special considerations on VOA samples.
6. Begin pouring slowly from the bailer.
7. Filter and preserve samples as required by sampling plan.
8. Cap the sample container tightly and place pre-labeled sample container in a carrier.
9. Replace the well cap.
10. Log all samples in the site logbook and on field data sheets and label all samples.
11. Package samples and complete necessary paperwork.
12. Transport sample to decontamination zone to prepare it for transport to analytical laboratory.

Submersible Pump

Although it is recommended that samples not be collected with a submersible pump due to the reasons stated in Section 2.4, there are some situations where they may be used.

1. Allow the monitoring well to recharge after purging, keeping the pump just above the screened section.

2. Attach gate valve to hose (if not already fitted), and reduce flow of water to a manageable sampling rate.
3. Assemble the appropriate bottles.
4. If no gate valve is available, run the water down the side of a clean jar and fill the sample bottles from the jar.
5. Cap the sample container tightly and place pre-labeled sample container in a carrier.
6. Replace the well cap.
7. Log all samples in the site logbook and on the field data sheets and label all samples.
8. Package samples and complete necessary paperwork.
9. Transport sample to decontamination zone for preparation for transport to analytical laboratory.
10. Upon completion, remove pump and assembly and fully decontaminate prior to setting into the next sample well. Dedicate the tubing to the hole.
3. Turn pump on, increase the cycle time and reduce the pressure to the minimum that will allow the sample to come to the surface.
4. Cap the sample container tightly and place pre-labeled sample container in a carrier.
5. Replace the well cap.
6. Log all samples in the site logbook and on field data sheets and label all samples.
7. Package samples and complete necessary paperwork.
8. Transport sample to decontamination zone for preparation for transport to analytical laboratory.
9. On completion, remove the tubing from the well and either replace the Teflon tubing and bladder with new dedicated tubing and bladder or rigorously decontaminate the existing materials.
10. Collect non-filtered samples directly from the outlet tubing into the sample bottle.
11. For filtered samples, connect the pump outlet tubing directly to the filter unit. The pump pressure should remain decreased so that the pressure build-up on the filter does not blow out the pump bladder or displace the filter. For the Geotech barrel filter, no actual connections are necessary so this is not a concern.

Non-Gas Contact Bladder Pump

The use of a non-gas contact positive displacement bladder pump is often mandated by the use of dedicated pumps installed in wells. These pumps are also suitable for shallow (less than 100 feet) wells. They are somewhat difficult to clean, but may be used with dedicated sample tubing to avoid cleaning. These pumps require a power supply and a compressed gas supply (or compressor). They may be operated at variable flow and pressure rates making them ideal for both purging and sampling.

Barcelona (1984) and Nielsen (1985) report that the non-gas contact positive displacement pumps cause the least amount of alteration in sample integrity as compared to other sample retrieval methods.

1. Allow well to recharge after purging.
2. Assemble the appropriate bottles.

Suction Pump

In view of the limitations of suction pumps, they are not recommended for sampling purposes.

Inertia Pump

Inertia pumps may be used to collect samples. It is more common, however, to purge with these pumps and sample with a bailer.

1. Following well evacuation, allow the well to recharge.
2. Assemble the appropriate bottles.

3. Since these pumps are manually operated, the flow rate may be regulated by the sampler. The sample may be discharged from the pump outlet directly into the appropriate sample container.
4. Cap the sample container tightly and place pre-labeled sample container in a carrier.
5. Replace the well cap.
6. Log all samples in the site logbook and on field data sheets and label all samples.
7. Package samples and complete necessary paperwork.
8. Transport sample to decontamination zone for preparation for transport to analytical laboratory.
9. Upon completion, remove pump and decontaminate or discard, as appropriate.

2.7.5 Filtering

For samples that require filtering, such as samples which will be analyzed for total metals, the filter must be decontaminated prior to use and between uses. Filters work by two methods. A barrel filter such as the "Geotech" filter works with a bicycle pump, which is used to build up positive pressure in the chamber containing the sample. The sample is then forced through the filter paper (minimum size 0.45 μm) into a jar placed underneath. The barrel itself is filled manually from the bailer or directly via the hose of the sampling pump. The pressure must be maintained up to 30 psi by periodic pumping.

A vacuum type filter involves two chambers, the upper chamber contains the sample and a filter (minimum size 0.45 μm) divides the chambers. Using a hand pump or a Gilian type pump, air is withdrawn from the lower chamber, creating a vacuum and thus causing the sample to move through the filter into the lower chamber where it is drained into a sample jar, repeated pumping may be required to drain all the sample into the lower chamber. If preservation of the sample is necessary, this should be done after filtering.

2.7.6 Post Operation

After all samples are collected and preserved, the sampling equipment should be decontaminated prior to sampling another well. This will prevent cross-contamination of equipment and monitoring wells between locations.

1. Decontaminate all equipment.
2. Replace sampling equipment in storage containers.
3. Prepare and transport water samples to the laboratory. Check sample documentation and make sure samples are properly packed for shipment.

2.7.7 Special Considerations for VOA Sampling

The proper collection of a sample for volatile organics requires minimal disturbance of the sample to limit volatilization and therefore a loss of volatiles from the sample.

Sample retrieval systems suitable for the valid collection of volatile organic samples are: positive displacement bladder pumps, gear driven submersible pumps, syringe samplers and bailers (Barcelona, 1984; Nielsen, 1985). Field conditions and other constraints will limit the choice of appropriate systems. The focus of concern must be to provide a valid sample for analysis, one which has been subjected to the least amount of turbulence possible.

The following procedures should be followed:

1. Open the vial, set cap in a clean place, and collect the sample during the middle of the cycle. When collecting duplicates, collect both samples at the same time.
2. Fill the vial to just overflowing. Do not rinse the vial, nor excessively overfill it. There should be a convex meniscus on the top of the vial.
3. Check that the cap has not been contaminated (splashed) and carefully cap the vial. Place the cap directly over the top and screw down firmly. Do not overtighten and break the cap.

4. Invert the vial and tap gently. Observe vial for at least 10 seconds. If an air bubble appears, discard the sample and begin again. It is imperative that no entrapped air is in the sample vial.
5. Immediately place the vial in the protective foam sleeve and place into the cooler, oriented so that it is lying on its side, not straight up.
6. The holding time for VOAs is 7 days. Samples should be shipped or delivered to the laboratory daily so as not to exceed the holding time. Ensure that the samples remain at 4°C, but do not allow them to freeze.

2.8 CALCULATIONS

There are no calculations necessary to implement this procedure. However, if it is necessary to calculate the volume of the well, utilize the following equation:

$$\text{Well volume} = \pi r^2 h (\text{cf}) \quad [\text{Equation 1}]$$

where:

- π = pi
- r = radius of monitoring well (feet)
- h = height of the water column (feet)
[This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
- cf = conversion factor (gal/ft^3) = 7.48 gal/ft^3 [In this equation, 7.48 gal/ft^3 is the necessary conversion factor.]

Monitoring wells are typically 2, 3, 4, or 6 inches in diameter. If you know the diameter of the monitoring well, there are a number of standard conversion factors which can be used to simplify the equation above.

The volume, in gallons per linear foot, for various standard monitoring well diameters can be calculated as follows:

$$v = \pi r^2 (\text{cf}) \quad [\text{Equation 2}]$$

where:

- v = volume in gallons per linear foot
- π = pi
- r = radius of monitoring well (feet)
- cf = conversion factor (7.48 gal/ft^3)

For a 2-inch diameter well, the volume in gallons per linear foot can be calculated as follows:

$$\begin{aligned} v &= \pi r^2 (\text{cf}) \quad [\text{Equation 2}] \\ &= 3.14 (1/12 \text{ ft})^2 7.48 \text{ gal}/\text{ft}^3 \\ &= 0.1632 \text{ gal}/\text{ft} \end{aligned}$$

Remember that if you have a 2-inch diameter, well you must convert this to the radius in feet to be able to use the equation.

The volume in gallons per linear foot for the common size monitoring wells are as follows:

Well Diameter	v (volume in gal/ft)
2 inches	0.1632
3 inches	0.3672
4 inches	0.6528
6 inches	1.4688

If you utilize the conversion factors above, Equation 1 should be modified as follows:

$$\text{Well volume} = (h)(v) \quad [\text{Equation 3}]$$

where:

- h = height of water column (feet)
- v = volume in gallons per linear foot as calculated from Equation 2

2.9 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

- All data must be documented on field data sheets or within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless

otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

2.10 DATA VALIDATION

This section is not applicable to this SOP.

2.11 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures. More specifically, depending upon the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site health and safety plan should be reviewed with specific emphasis placed on the protection program planned for the well sampling tasks. Standard safe operating practices should be followed such as minimizing contact with potential contaminants in both the vapor phase and liquid matrix through the use of respirators and disposable clothing.

For volatile organic contaminants:

- Avoid breathing constituents venting from the well.

- Pre-survey the well head-space with an FID/PID prior to sampling.
- If monitoring results indicate organic constituents, sampling activities may be conducted in Level C protection. At a minimum, skin protection will be afforded by disposable protective clothing.

Physical hazards associated with well sampling are:

- Lifting injuries associated with pump and bailer retrieval; moving equipment.
- Use of pocket knives for cutting discharge hose.
- Heat/cold stress as a result of exposure to extreme temperatures (may be heightened by protective clothing).
- Slip, trip, fall conditions as a result of pump discharge.
- Restricted mobility due to the wearing of protective clothing.

APPENDIX E

**USGS OFR 90-140 – METHODS FOR COLLECTION
AND PROCESSING OF SURFACE-WATER AND BED-
SEDIMENT SAMPLES FOR PHYSICAL AND
CHEMICAL ANALYSES**

Methods for Collection and Processing of Surface-Water and Bed-Material Samples for Physical and Chemical Analyses

By Janice R. Ward and C. Albert Harr, Editors



U.S. GEOLOGICAL SURVEY
Open-File Report 90-140

METHODS FOR COLLECTION AND PROCESSING OF SURFACE-WATER AND BED-MATERIAL SAMPLES FOR PHYSICAL AND CHEMICAL ANALYSES

by

Janice R. Ward and C. Albert Harr, Editors

ABSTRACT

Many Federal, State, and local agencies and the private sector can make best use of water-quality data if data-collection and analysis techniques are standardized. This manual describes the methods used by the U.S. Geological Survey for the collection and processing of surface-water and bed-material samples for the determination of their chemical and physical characteristics. It complements the report entitled "Field Methods for Measurement of Fluvial Sediment" by T. K. Edwards and G. D. Glysson (U.S. Geological Survey Open-File Report 86-531, 118 p., 1988), and those procedures and equipment described in that publication are referenced rather than repeated in this one. This manual describes equipment and procedures used for sample handling, and the containers and reagents used for the storage, preservation, and shipment of samples.

INTRODUCTION

The purpose of this manual is to document and describe the procedures used by the U.S. Geological Survey for the collection and processing of water-sediment¹ samples from surface water and of material from the beds of surface-water bodies for physical and/or chemical analyses. Procedures for the collection and processing of samples for biological analysis are described in the U.S. Geological Survey Open-File Report 88-190 (Britton and Greeson, eds., 1988). Detailed discussion of field methods and equipment for measuring fluvial sediment is given in the U.S. Geological Survey Open-File Report 86-531 (Edwards and Glysson, 1988).

SAMPLE COLLECTION

Water-sediment samples are collected and analyzed to determine the chemical composition and the biological and physical characteristics of a water body; to determine its suitability for domestic, industrial, and agricultural uses; to aid in understanding the geochemical and hydrologic relations; and to evaluate human influences on these systems. An essential phase of the data-collection process, and one that is of primary importance to the accuracy of the final result, is obtaining representative samples for analysis. Errors introduced by sampling can be the most significant in the entire data-collection process. The degree to which a single sample can be considered representative of a large water body depends on several factors, which include the homogeneity of the water body sampled, the number of points sampled, the size of the individual samples, and the manner in which samples are collected.

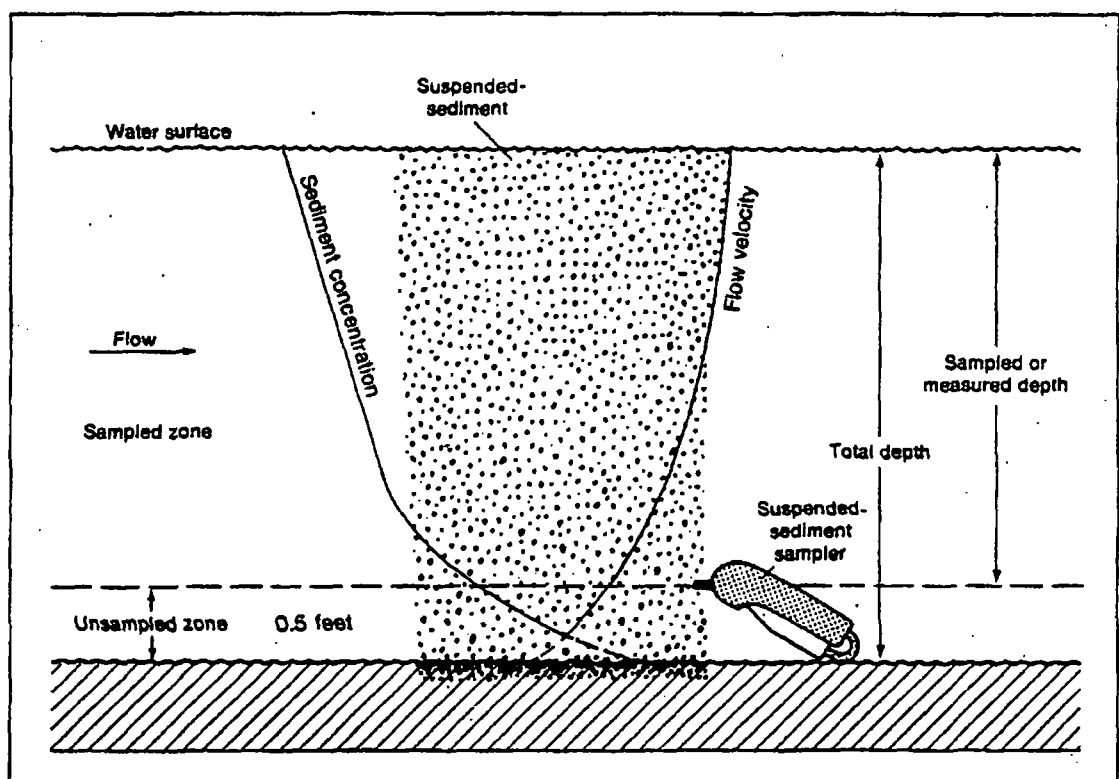
¹Used throughout this report, the term refers to water and/or a mixture of water and suspended sediment.

A stream or lake vertical, which is sampled using the depth- or point-integrated samplers discussed later, is shown in figure 1. The vertical is divided into a sampled zone and an unsampled zone, whose depths are determined by the design of the sampler. The unsampled zone generally carries a higher concentration and larger particles of sediment than the sampled zone. Sediment transported in this zone consists of both bedload and suspended-sediment load, whereas sediment transported in the sampled zone is almost entirely suspended-sediment load. Only the sampled zone will be addressed in this report.

Streams

Representative Sampling

The need for each sample, or set of samples taken nearly simultaneously, to represent the chemical composition and the biological and physical characteristics of the whole flow of a stream at the sampling point at an instant, and the need for enough samples distributed in time or space to define the changes that occur in the water passing the sampling point or along a stream course, need to be considered for representative sampling of



(Not to scale)

Figure 1. Sampled and unsampled zones in a stream sampling vertical with respect to velocity of flow and sediment concentration.

flowing waters. If the properties and conditions of a stream and the water in it were completely homogeneous, the collection of representative samples would be a simple task. However, because most streams are not homogeneous, the representativeness of samples depends on the equipment and collection method used.

Each sampling site needs to be examined and sampled in a manner that minimizes its disadvantages and maximizes its advantages. Physical factors, such as the amount of turbulence, velocity gradients, and proximity of inflows, partially determine the homogeneity of a stream at a cross section (fig. 2). Below the confluence of streams there can be a distinct separation due to differences in the concentration of dissolved solids, suspended sediment, or water temperature. The difficulties these features present in obtaining a sample representative of the flow past a point can be minimized by careful selection of the sampling-cross section. Theoretically, a sample representative of the mean composition can be obtained by combining depth-integrated samples of equal volume taken at points in the cross section representing segments of equal flow (Hem, 1970, 1985).

To obtain samples representative of the water-sediment mixture, the sampler needs to be filled isokinetically; that is, water approaching the sampler does not change in velocity or direction as it enters the intake. Thus, the concentration of sediment in the water-sediment mixture in the sampler and its concentration in the stream are equal (fig. 3a). If the velocity in the nozzle is less than the stream velocity in the vicinity of the sampler, the concentration of sediment in the water-sediment mixture in the sampler will be greater than its concentration in the stream (fig. 3b). Conversely, if the velocity in the nozzle is greater than the stream velocity

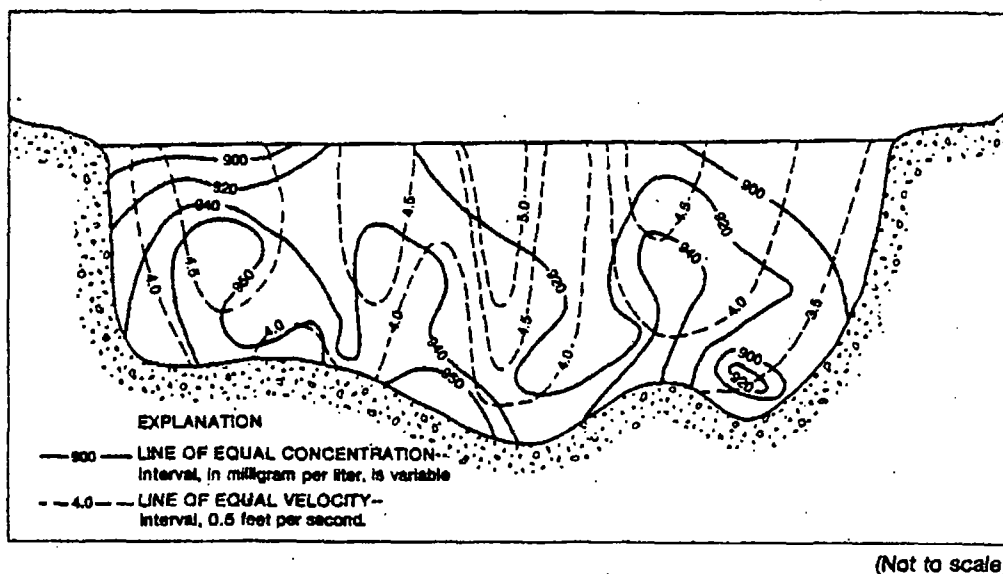
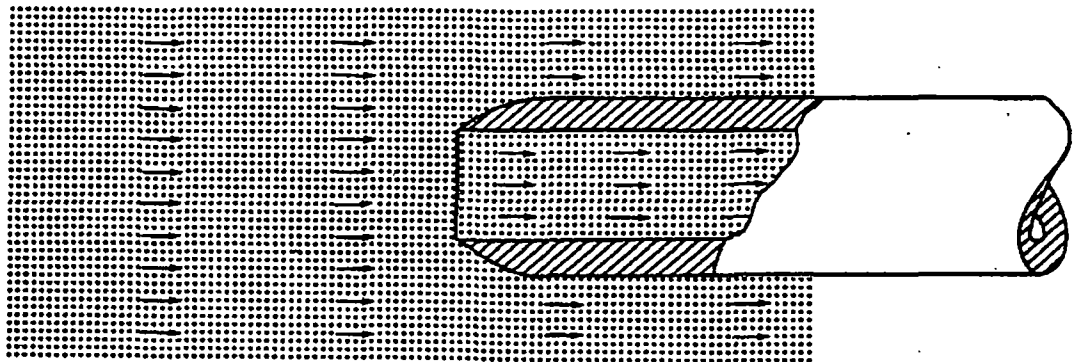
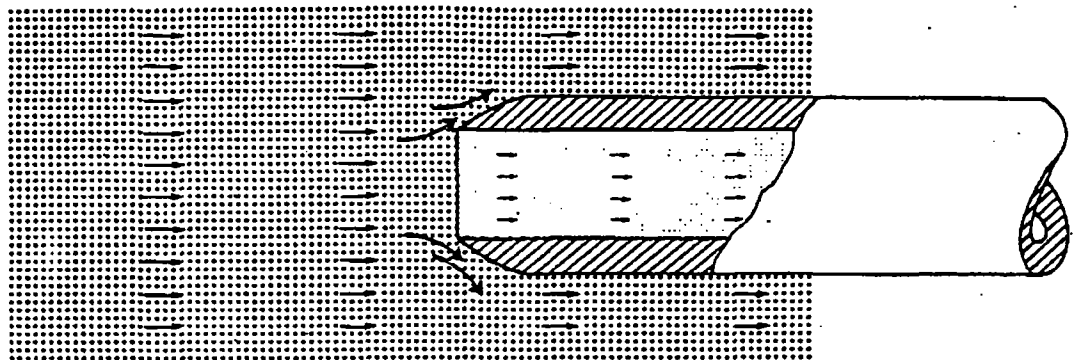


Figure 2. The distribution of stream velocity and concentration of a constituent in a stream cross section.



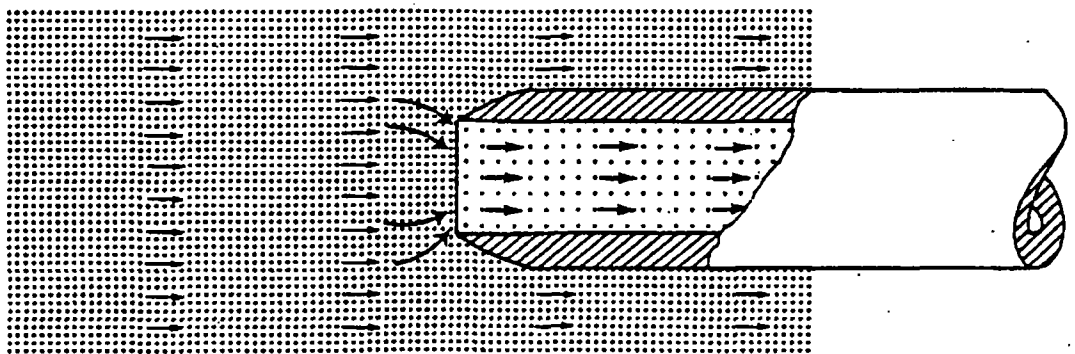
$$V_s = V_i; C_s = C_i$$

Isokinetic sampling



$$V_s > V_i; C_s < C_i$$

Non-isokinetic sampling



$$V_s < V_i; C_s > C_i$$

Non-isokinetic sampling

Figure 3. Relation between intake velocity and sample concentration for isokinetic and non-isokinetic sampling for particles greater than 0.62 millimeters. (V_s , velocity in stream; V_i , velocity in nozzle; C_s , concentration in stream; C_i , concentration in nozzle.)

in the vicinity of the sampler, the concentration of sediment in the water-sediment mixture in the sampler will be less than its concentration in the stream (fig. 3c). The magnitude of sampling error associated with these velocity differences increases with extent of departure from the isokinetic-velocity ratio and the particle size of suspended sediment. The magnitude of sampling error increases more rapidly with subnormal intake rates than with correspondingly supernormal rates.

The curvature of the flow pattern or any of its stream lines resulting from changes in velocity or direction or by disturbances due to the sampler will segregate suspended sediment from the water. The alteration of the concentration of suspended-sediment and sorbed constituents in the water-sediment mixture in the filament of flow entering the sampler also contributes to sampling error.

Preferred Methods

Samplers and sampling methods need to be designed so that they yield samples that accurately represent the water-quality characteristics of a stream at a given time and location. Five different sampling methods based on the use of isokinetic samplers are described below.

Single-Vertical Method

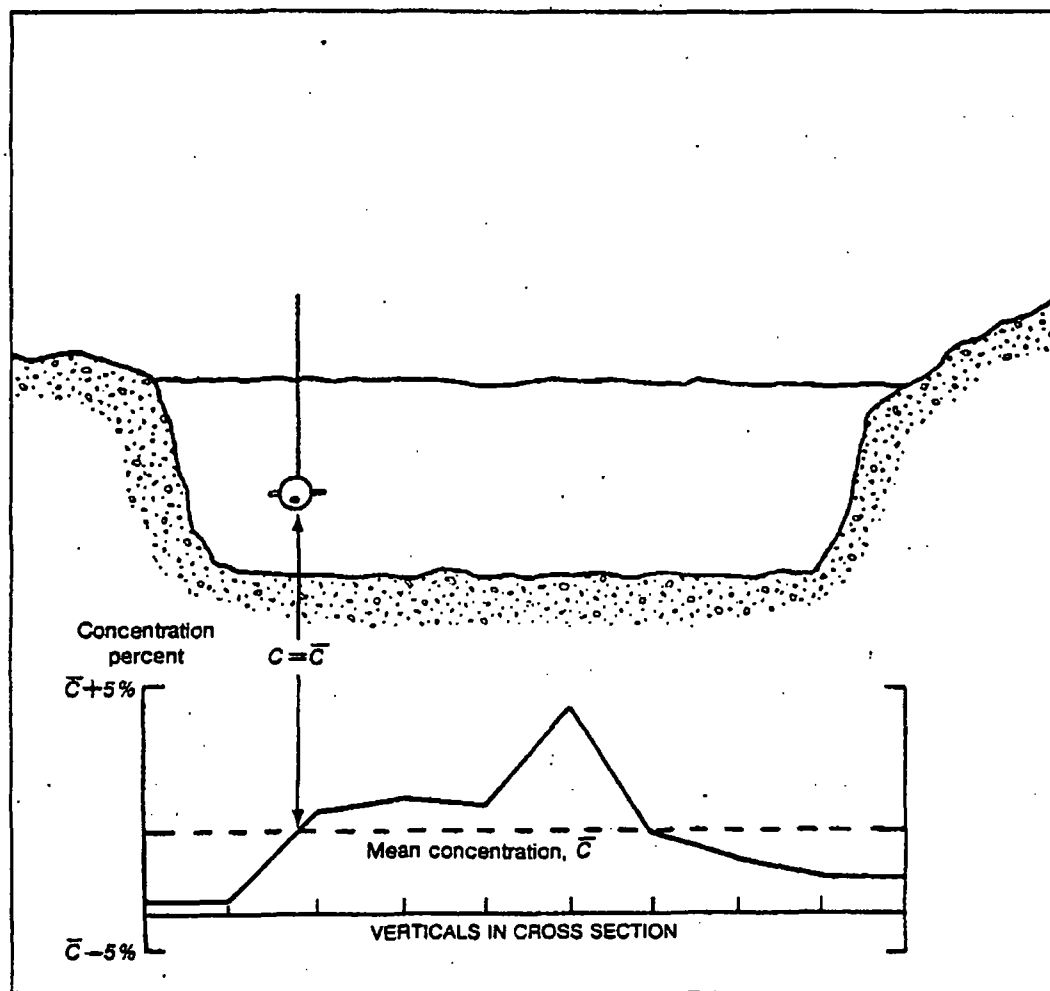
Uniform water-quality and streamflow conditions at many sampling sites will permit the collection of a representative depth-integrated sample by the single-vertical sampling method.

1--Application

The single-vertical sampling method is used to obtain a representative sample in the vertical being sampled at the precise time the sample is collected. It generally can be used in small streams where the streambed is stable; the water discharge is distributed uniformly in the cross section; and the water temperature, specific conductance, pH, and the dissolved-oxygen and suspended-sediment concentrations in the cross section do not deviate by more than five percent. Use of this method at various water discharges requires that cross-section uniformity be checked throughout the range of water discharges to be sampled. This method commonly is used at locations where a fixed (box) sampler is attached to a bridge or other structure for an observer to collect water-sediment samples for the determination of suspended-sediment concentration.

2--Description

When this method is used to collect a representative sample from small streams, the position of the single vertical in the cross section is selected after field reconnaissance and measurement of water temperature, specific conductance, pH, and the dissolved-oxygen and suspended-sediment concentrations. A depth-integrating sampler is lowered to the bottom and raised through the water column at a uniform transit rate not to exceed 0.4 of the mean stream velocity; the minimum rate needs to be such that the round trip does not result in an overfilled sample container. A detailed discussion of transit rates can be found in Edwards and Glysson (1988). The method is illustrated in figure 4.



(Not to scale)

Figure 4. The single-vertical sampling method. (Depth-integrated sample is collected at flow weighted mean concentration vertical.)

A few considerations of variations in sample collection for different stream velocities are noted below. If stream velocity is low enough so that no sand is suspended (<2.0 ft/s), distribution of silt and clay is generally uniform from the stream surface to the bottom (Guy, 1970, p. 15). In this case, the transit rate of the sampler is not critical. For velocities higher than 2.0 ft/s, transit rates need to be constant to obtain a representative sample. For high velocities (>10 ft/s), care needs to be taken when sampling to avoid any debris in the stream that may either damage the sampler or injure the field person. In cases of extreme velocity or heavy debris, it may only be possible to collect a surface or dip sample.

Multiple-Vertical Method

The multiple-vertical sampling method is the collection of several single-vertical samples in a cross section where the distribution of chemical constituents, suspended-sediment, and bed roughness vary markedly with dis-

tance across the stream and with time (Simons and Richardson, 1966; Guy, Simons, and Richardson, 1966).

The Geological Survey uses two basic methods to define the location of multiple verticals: the equal-discharge- and equal-width-increment methods.

Equal-Discharge-Increment Method

The EDI (equal-discharge-increment) sampling method, formerly known as the centroids-of-equal-discharge-increments method (Edwards and Glysson, 1988) provides a transect sample whose concentration is discharge weighted both vertically and laterally. The sample volume at each section is kept constant by varying the transit rate.

1--Application

The EDI method is used most often in streams that have stable channels and whose discharge ratings change very little during the year. It requires that the lateral distribution of water discharge be known or measured prior to sampling. It is preferable to not use this method for sandbed streams because flow distribution can change radically while the discharge measurement or sample is being taken. The EDI method can save time and labor over the EWI (equal-width-increment) method (discussed below), especially on larger streams because fewer sampling verticals are required (Hubbell and others, 1956). This method is also better than the EWI method in streams with rapidly changing stages because of the shorter sampling time required.

On the basis of the V^2/D index (defined in fig. 5) concepts of variability, P. R. Jordan (written commun., 1968) used data from Hubbell and others (1956) to prepare a nomograph (fig. 5) that indicates the number of sampling verticals required for a desired maximum acceptable relative standard error (sampling error) based on the percentage of sand and the V^2/D index. In the example illustrated by figure 5, the acceptable relative standard error is 15 percent, the sample is 100-percent sand, the V^2/D index is 2.0, and the required number of verticals is seven. Notice that if the sediment were 50-percent sand, the same results could be obtained with three verticals; or, if seven verticals were used with 50-percent sand, the relative standard error would be about 8 percent.

2--Description

A detailed description of this method is given by Edwards and Glysson, 1988.

Equal-Width Increment Method

The EWI sampling method, formerly known as the ETR (equal-transit-rate) method (Edwards and Glysson, 1988) provides a transect sample whose concentration is discharge-weighted both vertically and laterally and whose volume is proportional to the water discharge in the sampled zone.

1--Application

The EWI method commonly is used in shallow and/or sandbed streams where the distribution of water discharge in the cross section is not stable. An advantage of the EWI method is that knowledge of the lateral distribution,

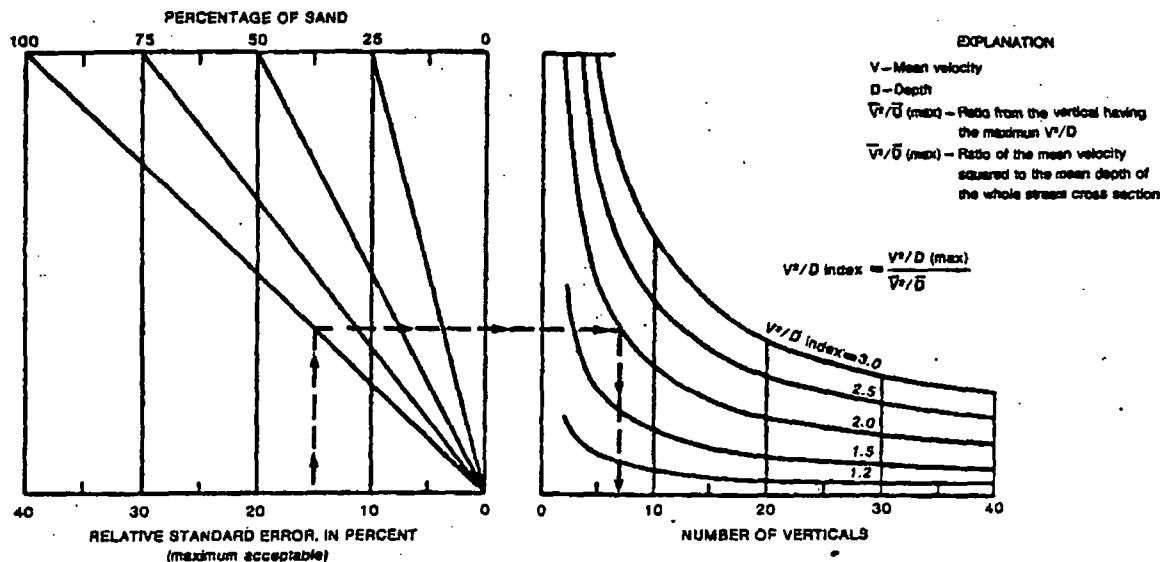


Figure 5. Nomograph to determine the number of sampling verticals required to obtain results within an acceptable relative standard error based on the percentage of sand in the sample and the V^2/D index. (Best results are obtained when V is between 2 and 5 and D is greater than 1.5 feet.)

of discharge is not required. However, it is sometimes difficult to maintain the same vertical transit rate at all verticals; more verticals need to be sampled than with the equal-discharge increment method; and wherever the flow is not perpendicular to the transect, the width increment between sampling verticals needs to be adjusted by the sine of the angle between the flow lines and the transect. The number of sampling verticals required depends on the distribution of concentration and streamflow in the cross sections as well as the desired relative standard error. Generally 10 to 20 verticals will provide an accurate mean discharge-weighted concentration of constituents.

2.--Description

A detailed description of this method is given in Edwards and Glysson, 1988.

Point-Integrating Method

The point-integrating sampling method provides a water-sediment sample from a fixed point in a vertical.

1--Application

The point-integrating sampling method is used to collect water-sediment samples from one or several points in a vertical to define vertical distribution in a stream, lake, reservoir, or estuary.

2--Description

A detailed detailed description of this method is given in Edwards and Glysson, 1988.

Equipment

Many samplers are available for the purpose of collecting water and suspended-sediment samples. Most perform well under the conditions for which they were designed, but no single sampler is capable of collecting a correct sample under all conditions. A detailed discussion of the equipment used by the Geological Survey for the collection of water and suspended-sediment samples from streams for chemical and physical analysis is given in Edwards and Glysson, 1988.

Isokinetic Samplers-Principles and Use

Three criteria for the design of integrating-type samplers need to be met for an isokinetic sampler (Subcommittee on Sedimentation, Federal Inter-Agency River Basin Committee, 1952). These criteria are: (a) the sampler needs to fill at a rate such that the velocity in the nozzle at the point of intake and local stream velocity are equal; (b) the intake nozzle needs to point into the stream parallel to the lines of flow and project sufficiently far in front of the sampler body so that stream lines are not altered by the sampler body; and (c) the sampler needs to have a separate intake and air exhaust to permit smooth sampling. Additional design criteria require that: (a) the sampler has a removable sample container; (b) it permits sampling close to the streambed; (c) it needs to be streamlined and heavy enough to eliminate excessive downstream drag; (d) it has a rudder and lateral vanes to orient the sampler parallel to the flow if suspended by cable; and (e) it is of simple and sturdy construction.

Isokinetic samplers are either depth-integrating or point-integrating. Depth-integrating samplers can be used to collect water-sediment samples from depths of 8.86 to 19 ft, depending on nozzle and container sizes. Point-integrating samplers can be used at depths of 51 to 180 ft. They also may be used for depth integration when the depth to be sampled exceeds 19 ft. Both types of samplers are designed for use in moving water.

US Series Manual Samplers

The US series of manual samplers designed, built, tested, and distributed by the Federal Inter-Agency Sedimentation Project are classified as either depth-integrating or point-integrating. A depth-integrating sampler is designed to collect a representative water-sediment sample from a stream vertical by matching the velocity of water entering the nozzle at the point of intake to the stream velocity and by moving through the vertical at a uniform rate. A point-integrating sampler is designed to collect a representative sample in the same way as a depth-integrating sampler, or at a single point in a vertical.

The characteristics and uses of available samplers are presented in table 1. and discussed in detail in Edwards and Glysson, 1988. Most of the samplers are also available with epoxy-painted bodies and silicone-rubber gaskets, where appropriate, for the collection of samples for the determination of trace metals.

Automatic Samplers

In addition to the manual samplers in table 1, there are seven automatic samplers. They are designed for the collection of water-sediment samples at remote, or not easily accessible, sites where conventional sampling is not practical, or for flashy or intermittent streams where personnel might not be able to be present during sampling. There are two nonpowered samplers; US U-59 (or SS-59) and U-73, and five powered, pumping samplers; US PS-69, US CS-77, US PS-82, Manning² S-4050, and ISCO 1680. A detailed discussion of these samplers is given in Edwards and Glysson, 1988.

The U-59 and U-73 samplers are similar to point samplers because they are used to collect a single sample at a single point in the stream vertical. Samples generally are collected near the surface and either near the stream-bank or a pier or abutment where it is easy to fasten the sampler in place. Depth-integrated samples generally are not obtained. Intake velocity also generally does not match stream velocity, so that the sample might not even be representative of the point at which it was collected. These samplers were designed mainly for sediment studies and have not been widely used in water-quality studies.

Of the five generally available automatic pumping samplers, the US PS-69 is probably the most widely known and used by Geological Survey personnel. All pumping samplers have the following basic characteristics: (1) a pump to draw a suspended-sediment sample from the streamflow and, in some cases, to provide a back-flush to clear the sampler plumbing before or after each sampling cycle; (2) a sample container unit to hold sample bottles in position for filling; (3) a sample distribution system to divert a pumped sample to the correct bottle; (4) an activation system that starts and stops the sampling cycle, either at some regular time interval or in response to a rise or fall in streamflow (gage height); and (5) an intake system through which samples are drawn from a point in the cross section. Some specific criteria of each of the samplers are summarized in table 2.

Use of an automatic pumping sampler instead of conventional hand sampling can be as labor intensive and commonly more costly than hand sample collection. Installation requires careful selection of location, intake placement, and detailed background data to ensure meaningful pumped sample data. Numerous hand samples need to be collected to verify the representation of the automatic samples for both depth-integration and cross-section representation. This verification needs to be done for all constituents of concern. A detailed discussion of installation and data analyses concerns are given in Edwards and Glysson, 1988.

² Reference to trade names, commercial products, manufacturers, or distributors in this manual is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 1. Sampler designations and characteristics

(Epoxy-coated versions of all samplers are available for collecting samples for the determination of trace metals.)

Designation US —	Construction Material	Sampler Length (inches)	Sampler Width (inches)	Sampler weight (pounds)	Nozzle distance from bottom (inches)	Suspension	Maximum tested Velocity (feet per second)	Depth (feet)	Sampler Container size Pint Quart X = available -- = not available	Intake nozzle Size (inches)	Color	Special applications
DB-40	Aluminum	13	3.2	4.5	3.5	Rod	8.86	8.86	X --	1/4	Yellow	Modified version available for square pint milk bottles
DB-75P	Cadmium-plated	9.25	4.25	1.5	3.27	Rod	6.6	16	X --	3/16	White	Freezing conditions
DB-75Q	Cadmium-plated	9.25	4.25	1.5	4.49	Rod	6.6	16	-- X	3/16	White	
DB-75H	Cadmium-plated	9.25	4.25	1.5	--	Rod	6.6	--	(2 liter)	3/16	White	
DB-59	Bronze	15	3.5	22	4.49	Handline	5.0	19	X --	1/8	Red	
DB-59	do.	15	3.5	22	4.49	do.	5.0	16	X --	3/16	Red	
DB-59	do.	15	3.5	22	4.49	do.	5.0	9	X --	1/4	Red	
DB-76	Bronze	17	4.5	22	3.15	Handline	6.6	16	-- X	1/8	Red	
DB-76	do.	17	4.5	22	3.15	do.	6.6	16	-- X	3/16	Red	
DB-76	do.	17	4.5	22	3.15	do.	6.6	16	-- X	1/4	Red	
DB-81	Plastic	7.5	4.0	0.5	(5)	Rod	8.9	(8)	(7) --	3/16	White	Bacterial sampling, freezing conditions
DB-81	do.	7.5	4.0	0.5	(5)	do.	8.9	9	(7) --	1/4	White	
DB-81	do.	7.5	4.0	0.5	(5)	do.	8.9	9	(7) --	5/16	White	
D-49	Bronze	24	5.25	62	4.00	Cable reel	6.6	19	X --	1/8	(8)	
D-49	do.	24	5.25	62	4.00	do.	6.6	16	X --	3/16	(8)	
D-49	do.	24	5.25	62	4.00	do.	6.6	9	X --	1/4	(8)	

Table 1. Sampler designations and characteristics--Continued

Designation US --	Construction material	Sampler		Sampler weight (pounds)	Nozzle distance from bottom (inches)	Suspension	Maximum tested		Sampler Container size		Intake nozzle		Special applications
		Length (inches)	Width (inches)				Velocity (feet per second)	Depth (feet)	Pint	Quart	Size (inches)	Color	
D-74	Bronze	24	5.25	62	4.06	Cable reel	6.6	¹ 19, ² 16	³ X	X	1/8	Green	
D-74	do.	24	5.25	62	4.06	do.	6.6	¹ 19, ² 16	³ X	X	3/16	Green	
D-74	do.	24	5.25	62	4.06	do.	6.6	¹ 19, ² 16	³ X	X	1/4	Green	
D-74AL	Aluminum	24	5.25	42	4.06	Cable reel	5.9	¹ 19, ² 16	³ X	X	1/8	Green	
D-74AL	do.	24	5.25	42	4.06	do.	5.9	¹ 19, ² 16	³ X	X	3/16	Green	
D-74AL	do.	24	5.25	42	4.06	do.	5.9	¹ 19, ² 16	³ X	X	1/4	Green	
D-77	Bronze	29	9	75	7	Cable reel	8.0	15.5	(3 liter)		5/16	White	Bacterial sampling, large volume, freezing conditions
P-61	Bronze	28	7.34	105	4.29	Cable reel	6.6	¹ 180, ² 120	³ X	X	3/16	Blue	High velocity
P-63	Bronze	37	9	200	5.91	Cable reel	6.6	¹ 80, ² 120	³ X	X	3/16	Blue	
P-72	Aluminum	28	7.34	41	4.29	Cable reel	5.3	¹ 72.2, ² 50.9	³ X	X	3/16	Blue	

- 1/ Depth using pint sample container.
2/ Depth using quart sample container.
3/ Pint milk bottle can be used with adapter sleeve.
4/ Without sample bottle attached.
5/ Depends on bottle size used.
6/ Refer to transit-rate diagram construction (page ___) with specific nozzle and bottle size used.
7/ Any size bottle with standard mason jar treads.
8/ No specific color code has been assigned to D-49 nozzles as original equipment nozzles were constructed of brass and plastic replacements must be obtained from Federal Inter-Agency Sedimentation Project on a special order basis.

Table 2. Automatic pumping-type sampler evaluation
 [A = US PS-69; B = US CS-77; C = US PS-82;
 D = Manning S-4050; E = ISCO 1680]

Evaluation criteria	Samplers meeting criteria
1. Sample collection Isokinetic	
2. Sediment concentration constant stream to sample container	² A, ¹ B, ² C, D
3. Cross contamination prevented	A, B, C, D
4. Collects concentrations to 50,000 milligrams/liter and particles to 0.25 millimeters	² A, ^{2/1} B, ² C, ² D, ¹ E
5. Sample volume ≥ 350 milliliters	³ A, ³ B, ³ C, ³ D, ³ E
6. Intake diameter 3/4 inch	A
7. Turbulent flow (R = 4,000) within sampler	³ A, ¹ B, ² C, ³ D, ³ E
8. Vertical pumping lift ≥ 35 feet	¹ A, ¹ B, ¹ C
9. Capable of collecting an adequate number of samples to accomplish the purpose of sampling	³ A, ³ B, ³ C, D, E
10. Sampler protected against freezing, evaporation, and dust	¹ A, ¹ B, C, ¹ D, ¹ E
11. Sample container tray removable single unit	A, D, E
12. Sampling cycle activated by timer or stage change	A, B, C, D, E
13. Capable of recording sample date and time	¹ A, B, ¹ C, ¹ D, ¹ E
14. Alternating current or direct current power capacity	¹ A, ¹ B, ¹ C, ¹ D, ¹ E
15. Sampler or principle components ≤ 100 pounds	¹ A, ¹ B, ³ C, ³ D, ³ E
16. Sampler dimensions ≤ 35 by 79 inches	¹ A, ¹ B, ³ C, ³ D, ³ E
17. Required floor space ≤ 9 square feet (3 by 3 feet)	³ C, ³ D, ³ E

¹Sampler requires modification to meet criteria.

²Sampler shows a reduction in capacity with particle sizes ≥ 0.250 millimeters.

³Sampler exceeds criteria.

Open-Mouth Water-Sampling Bottles

Open-mouth bottles are the simplest samplers used for the collection of water samples. They generally consist of a glass or plastic bottle housed in a weighted support frame for submergence. Two types of open-mouth bottles, weighted bottles and bottle baskets, are described below.

Weighted bottles consist of an open-mouth glass or plastic bottle housed in a short length of pipe. The sample bottle is inserted into the pipe and secured underneath by a bolt which extends through the pipe at the bottom. The upper end is sewn with two "ears" drilled to accommodate a length of sash chain attached to a ring that slips over the neck of the bottle (fig. 6).

Bottle baskets are typically a frame made of strap iron (fig. 6) that supports the sample bottle. A lead or iron weight of sufficient size to overcome buoyancy is attached to the bottom of the basket to submerge the sampler. An open-mouth glass or plastic bottle is held in place by a ring, ring and chain, or loop of suspension line over its neck.

Open-mouth water-sampling bottles do not sample isokinetically, and collect only quasi-depth-integrated samples. The capacity of the samplers ranges from about 500 to 4,000 mL. The sampling depth is controlled by the capacity of the bottle and the rate of filling. Relatively representative samples can be collected from streams when the suspended sediment is uniformly distributed in the vertical and the velocity is less than 2.0 ft/s (Edwards and Glysson, 1988). These bottles can also be used in shallow streams where there is not much variation in composition in the vertical.



Figure 6. Weighted bottle and bottle basket.

Sampling Procedures

Sampling procedures for the collection of water-sediment samples from streams for analysis of water quality are the same as those required for analysis of fluvial sediment. A detailed description of procedures and equipment is given in Edwards and Glysson, 1988.

Lakes, Reservoirs, and Estuaries

Interest in refining the techniques for sampling lakes, reservoirs, and estuaries has grown because of increased interest in assessing their water-quality characteristics and in studying processes such as transport and eutrophication. As studies of these water bodies become more complex, sampling techniques for data collection require increased accuracy and consistency.

Representative Sampling

The probability that a single sample of a lake, reservoir, or estuary will be representative is slight. Even the concept of a representative sample has little utility. A single sample normally will be used only for reconnaissance purposes. Multiple samples describe three-dimensional variations in water-quality characteristics. In most investigations it is the three-dimensional variations that are of interest, and sampling programs normally are designed and conducted to meet that objective.

Three-dimensional variations in the water-quality characteristics of lakes and reservoirs result from the interaction of several interrelated physical, chemical, and biological processes. Physical processes include: (1) circulation patterns; (2) thermal, chemical, and density stratification; (3) morphometry of the lake or reservoir; (4) length of exposure to the sun and winds; (5) inflow and outflow patterns; (6) position and operation of outflow structures at dams; and (7) latitude of the lake or reservoir. Temperature probably is the major controlling factor for chemical and biological processes. These latter processes also are controlled by light penetration, dissolved-oxygen and nutrient concentration and biomass. Comprehensive discussions of these processes are given in texts on limnology, such as Hutchinson (1957).

Estuaries are dynamic systems, presenting a continually changing system that needs to be considered if successful sampling is to be accomplished. Estuaries may have large areas with low velocities that might be stratified; these areas generally are sampled like lakes and reservoirs. Near inlets and outlets where velocities can be much higher, sampling techniques for streams might be more appropriate. Freshwater inflow, circulation, and the tidal cycle affect estuarine water quality. The tide, which varies on daily, lunar, and annual cycles, might have identical stages as many as four times daily, yet water-quality characteristics are likely to be different each time.

Probably the most important aspect of sampling lakes, reservoirs, and estuaries is the design of the sampling program. The objectives of the sampling program (whether a reconnaissance or comprehensive survey) and the hydrologic and physical characteristics of the water body govern the choice of the location and number of sampling sites. Two schemes, dispersed random sampling and transect sampling, are preferable for planning the distribution of sampling sites. Dispersed random sampling requires that samples be collected from sites scattered over the area and that conscious choice in the

selection of sampling sites be rigorously excluded. Transect sampling requires that samples be taken randomly or at regular intervals along a predetermined line extending across the area concerned (Welch, 1948). The advantages of transect sampling are that the location and number of sampling sites are known and it may be easier to distribute sites over the area concerned while maintaining the requirements of random sampling.

Preferred Methods

Great care needs to be taken in the choice of methods whereby water-sediment samples are collected from lakes, reservoirs, and estuaries because the samples need to be taken at a known depth and need to be brought to the surface in a strictly unmodified condition. Samples are most commonly collected using a water-sampling bottle or pump.

Sampling with water-sampling bottles meets the above sampling requirements if the equipment is in good condition and properly used. Advantages include the ability to sample thin stratum, simplicity, light weight, and modest cost. The principal disadvantage is that repeated trips to the selected depth are needed to obtain large quantities of sample.

Pumping requires the use of a suitable pump which, when fully primed, has no leaks or air spaces. The fundamental disadvantage of pumping is the likely failure to meet the requirement of sampling from one thin definitely known stratum because water moves radially from unknown distances into the pump. Although this may not be serious if small amounts of water are needed, it needs to be remembered that before samples are collected, the pumping system needs to be filled with water from the stratum selected. Pumps and intake lines can also be costly and difficult to handle. Some or all of these disadvantages can be eliminated by choice of equipment.

Equipment

Depth- and point-integrating samplers, described previously, are not suitable for collecting water-sediment samples from slow-moving waters such as lakes, reservoirs, and some areas of estuaries. Equipment for sampling these waters must collect a sample at an exactly known depth, and needs to deliver the sample to the surface intact and unchanged. The sampling equipment described below meet these general sampling requirements, if used and maintained properly.

Van-Dorn Type Water-Sampling Bottles

1--Application

Van-Dorn type water-sampling bottles are used to collect instantaneous point water-sediment samples from lakes, reservoirs, and some areas of estuaries. They also can be used to collect point samples from streams if the velocity is less than 1.5 ft/s. The horizontal configuration water-sampling bottle is best for sampling at shallow depths. Vertical configuration water-sampling bottles can be linked in series for simultaneous sampling at several depths. The bottles are available in several different materials, suitable for sampling all inorganic constituents, including trace metals, and halogenated hydrocarbons.

2--Description

The Van-Dorn type water-sampling bottle (fig. 7) consists of an acrylic or PVC (polyvinyl chloride) plastic tube with end seals, a messenger-operated closing device, and spring-loaded drain valve for sample removal. Bottle capacity ranges from 2.2 to 30.2 L. The 2.2 L bottle is 4.5 in. in diameter and is 13.8 in. long; the 30.2 L sampler is 8.9 in. in diameter and is 43.0 in. long.

There are two styles of Van-Dorn water-sampling bottles. The alpha-style bottle has molded semirigid neoprene rubber end seals. The beta-style bottle has machined rigid neoprene rubber end seals; it is also available with rigid silicone rubber end seals and nonmetallic parts for collecting samples for determination of trace metals and halogenated hydrocarbons. Both styles of bottles are available in either vertical or horizontal configurations.

Kemmerer-Type Water-Sampling Bottles

1--Application

Kemmerer-type water-sampling bottles are used to collect instantaneous point water-sediment samples from lakes, reservoirs, and some areas of estuaries. They can also be used to collect point samples from streams if the velocity is less than 1.5 ft/s. The bottles can be used singly or in series to simultaneously collect samples at several depths. The bottles are available in several different materials, suitable for sampling all inorganic constituents, including trace metals, and halogenated hydrocarbons.

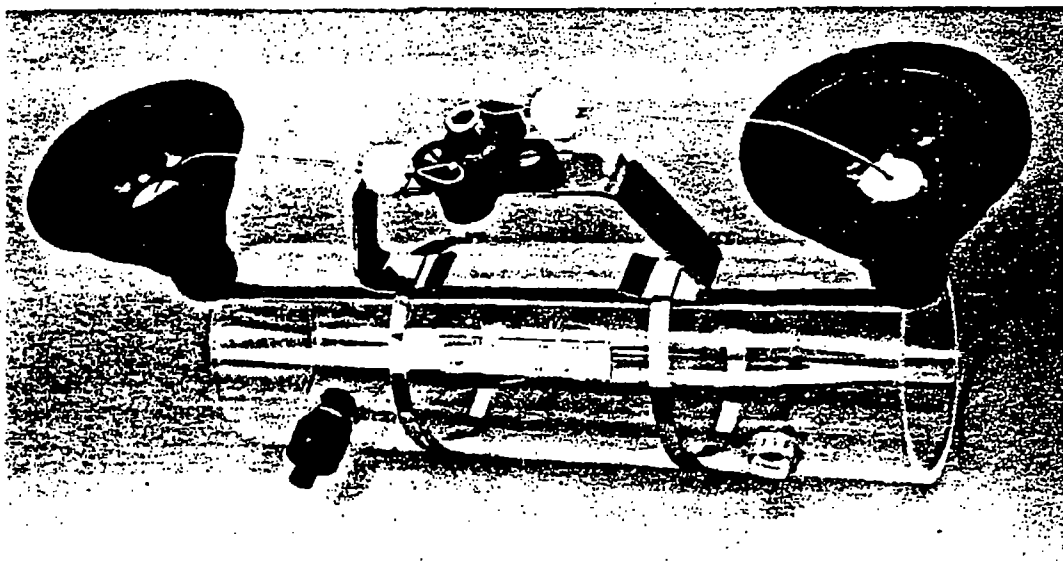


Figure 7. Van Dorn type water-sampling bottle (alpha horizontal style).
(Photograph courtesy of Wildlife Supply Company.)

2--Description

The Kemmerer-type water-sampling bottle (fig. 8) consists of a metallic or nonmetallic tube with end seals, a valve for sample removal, and a triggering device for closing. The brass or nickel-plated brass samplers range from 2.6 to 4.5 in. in diameter and from 16.8 to 45.5 in. in length. Capacity ranges from 0.4 to 8.2 L. A hollow brass tube extends through the center and supports neoprene rubber seals at the top and bottom. The top of the inner tube is enlarged and engages with a tripping device when the bottle is open. There is a spring-loaded valve in the bottom seal for sample removal. The acrylic or PVC plastic bottles range from 3.0 to 6.6 in. in diameter and from 16.8 to 45.5 in. in length; capacity ranges from 0.4 to 16.2 L. Plastic bottles are available with PVC components and silicone-rubber seals for the collection of samples for the determination of trace metals. A specially designed bottle is also available for the collection of samples for the determination of halogenated hydrocarbons.

Nansen-Type Water-Sampling Bottles

1--Application

The Nansen-type water-sampling bottle was designed primarily for oceanographic sampling, and is used most often in series. As many as 18 bottles can be attached to an oceanographic wire to collect nearly simultaneous point water-sediment samples at different depths. Because of the limited capacity of the Nansen bottle, several lowerings might be required to obtain sufficient sample volume for analysis. A Teflon-lined Nansen bottle is available for collecting samples for the determination of trace metals. The need to lubricate moving parts and seals in the bottle with penetrating oil and stopcock grease precludes its use for collecting samples for organic analysis. Each Nansen bottle is also fitted with a detachable deep-sea-reversing thermometer frame to hold a thermometer for measuring temperature at a given depth.

2--Description

The Nansen-type water-sampling bottle is a reversing-water bottle made of metal with a 1.25 L capacity (fig. 9). The bottle is fitted at both ends with tapered-plug valves, joined with a connecting rod. The lower end of the bottle is securely attached to an oceanographic wire with a clamp, and the upper end is hooked to the wire by a tripping mechanism.

Open-Mouth Water-Sampling Bottles

1--Application

Depth-integrated water-sediment samples can be collected from lakes, reservoirs, and some areas of estuaries by using open-mouth water-sampling bottles. As the bottle is lowered through a vertical, the rate of filling can be controlled by a one-hole rubber stopper. The depth that can be sampled is controlled by the size of bottle and the rate of filling. Point water-sediment samples can also be collected by fitting a solid stopper in the sample bottle, which can be removed by an attached line at the selected depth.

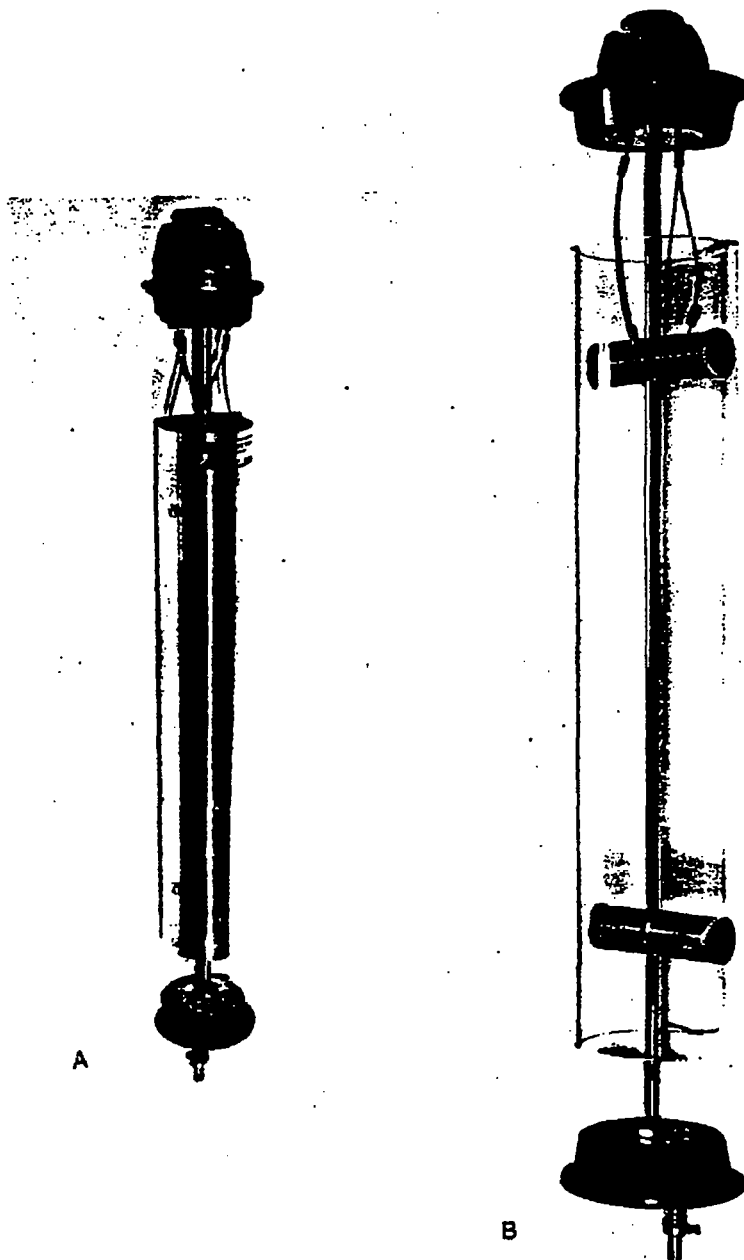


Figure 8. Kemmerer-type water-sampling bottles: (A) Metallic tube, (B) acrylic plastic tube. (Photograph courtesy of Wildlife Supply Company.)

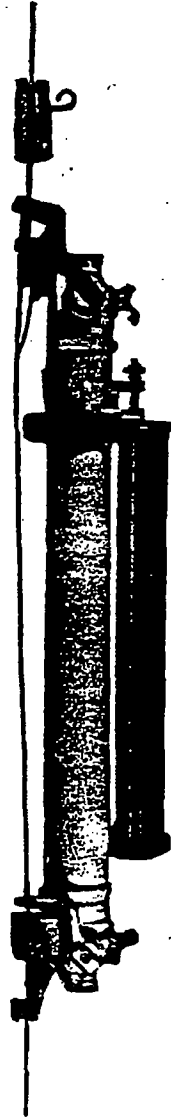


Figure 9. Nansen-type water-sampling bottle. (Photograph courtesy of Wildlife Supply Company.)

2--Description

Two types of open-mouth water-sampling bottles have been described previously and shown in figure 6. Bottles of various capacities can be made as needed.

Pumps

1--Application

The ability to collect large volume point water-sediment samples from lakes, reservoirs, and estuaries is the principal advantage of using pumps. Pumps can also be used to collect time-integrated samples from estuaries during tidal cycles. The use of pumps is restricted by the availability of power, length of intake or discharge line, and size of vessel required for the sampling operation. In addition, it is difficult to collect samples from a narrow stratum because water moves into the end of the intake line from all directions, and the radial distance that the sample is pulled from at the end of the intake is unknown. When taking a series of samples, water already filling the pump and intake line needs to be evacuated and replaced by water from the new sampling depth. This generally entails pumping a considerable quantity of water. It is uncertain how much of this water has come from other strata (Welch, 1948, p. 201).

2--Description

Suction-lift pumps (centrifugal and peristaltic) and positive-submergence pumps (submersible) are commonly used for sampling lakes, reservoirs, and estuaries. Suction lift pumps do not apply any force directly on the water. Lift is accomplished by developing a negative-pressure head (less than atmospheric pressure) at the pump intake. Atmospheric pressure on the water surface or higher pressure below the water surface forces water into the intake and pump. Positive submergence pumps have a pump unit submerged in the water below the pumping level. A positive-pressure head (greater than atmospheric pressure) forces water into the intake. Detailed discussion of these pumps is given below.

Sampling Procedures

Lakes and Reservoirs

1--Application

Water-sediment samples are most commonly collected in lakes and reservoirs by pumping or by discrete or point sampling with water-sampling bottles. The location and number of sampling sites depends on the objectives of the study and the hydrologic and physical characteristics of the lake or reservoir.

Each lake or reservoir is unique and has its own set of conditions for which a sampling program needs to be based. In small lakes or reservoirs with regular shore lines and uniform bottom configuration, a single site near the middle or in the deepest area may be sufficient to describe the distribution and abundance of constituents. In large, diversified lakes and reservoirs a single site is not adequate. Because each individual lake or reservoir may require a different design of the sampling program, no standard set of rules for locating sampling sites can be made that apply in all situations. However, consider selecting sites: (1) at or near inflows and outflows; (2) in the deepest area or at each submerged depression; (3) in partly enclosed bays and coves; (4) in extensive shallow areas; (5) in the vicinity of lee and windward shores; (6) behind large islands and peninsulas; and (7) in the vicinity of marsh or swamp shores. In addition, consider selecting sites along significantly placed transects or at randomly selected positions scattered over all open water.

2--Preferred Methods

There is no single preferred method for collecting water-sediment samples from lakes and reservoirs; the one selected depends on the application. Pumping has the advantage of producing a large volume of sample. The principal disadvantage is the difficulty of obtaining a sample from a thin stratum of the water column. Other disadvantages include the need for an external power source, weight, and difficulty in handling. Discrete sampling with water-sampling bottles has the advantage of being able to sample thin stratum. The principal disadvantage is the relatively small volume of sample collected, which might require repeated sampling.

3--Equipment

The equipment selected for obtaining water-sediment samples from lakes and reservoirs depends on the application. Van-Dorn and Kemmerer-type water-sampling bottles of sufficient capacity for the volume requirements of the analysis to be made are most commonly used. The horizontal style Van-Dorn type bottle is preferred because of its ability to sample thin strata. If trace metals are to be determined, an all plastic trace-metal version of the bottle needs to be used.

Peristaltic pumps, similar to those used for peristaltic-pumping filtration systems (see discussion of filtration of water samples below) also are preferable for sampling. These pumps have low-power requirements; can be used to obtain samples for the determination of trace metals; do not require heavy auxiliary equipment, such as hoists and hose reels; and reduce the difficulty of sampling thin strata. Boats of sufficient capacity for equipment and personnel are needed as sampling platforms. Small centrifugal and submersible pumps can also be used to collect larger volumes of sample.

4--Procedures

After the location of sampling sites has been selected, measurements of depth, water temperature, specific conductance, dissolved-oxygen concentration, and pH need to be made at each vertical to guide the selection of sampling depth. Measurement of the depth of light penetration also might be needed. These measurements determine the position and depth of the epilimnion, metalimnion or thermocline, and hypolimnion, and whether the bottom of the lake or reservoir is oxic or anoxic.

The availability of multi-parameter instrumentation for simultaneous measurement of these physiochemical properties has greatly simplified the task. The instruments need to be calibrated according to standard procedures and the measurements made with care. At each depth in the vertical, do not record measurements until the instrument has had sufficient time to equilibrate.

Once sampling depths are determined, sample with Van-Dorn or Kemmerer-type water-sampling bottles as follows: (1) check the bottle to make sure it is not damaged and lay out the supporting line free of knots; (2) cock the end valves in the open position and slowly lower the bottle to the sampling depth (it has been shown that movement of the bottle through the water column causes slight disturbances, but they are not serious if care is taken); (3) release the messenger to trip the closing mechanism; (4) raise the filled bottle to the surface; and (5) drain the sample from the bottle and process for analysis. The procedure is repeated at each sampling depth in the

vertical and for each sampling site. To hold the boat in position, particularly if a wind is blowing, both bow and stern anchors are to be used.

The procedure for sampling with pumps is similar to that with bottles. The weighted intake hose or submersible pump is lowered using a hoist to sampling depth and the pump is turned on. Water is pumped to clear the intake hose and insure that water from the sampling depth is being obtained. The sample is collected and processed for analysis. The procedure needs to be repeated at each sampling depth in the vertical and for each sampling site.

Estuaries

1--Application

Most of the sampling problems and procedures associated with lakes and reservoirs also occur in estuaries. Design of a sampling strategy in an estuary need to consider: (1) short term, generally nonrepetitive water movement driven by inflow, tides of variable amplitude, and winds of variable velocity superimposed on a migrating saltwater-freshwater interface; and (2) transport and deposition of dissolved and suspended constituents from inland sources, coupled with similar transport and deposition from oceanic sources and the mixing of constituents, complicated by water movement, differences in ionic strength of freshwater and saltwater, and changes in pH and water temperature.

The usual objective in sampling estuaries is to obtain synoptic measurements of water-quality characteristics at some appropriate point in the tidal cycle, generally slack water at high or low tide. At high or low tide, water moves from point to point so that the water sampled at one point was at another point some time earlier. Vertical mixing by tidal action frequently is not sufficient to smooth out variations; thus the description of water-quality characteristics from data collected at high or low tide can easily be confused and spatially inaccurate.

Preferable sampling techniques in estuaries are to collect samples at single points, or discrete sampling, throughout the vertical. Regardless of which technique is used, the location of the sampling point in the vertical needs to be known so that the point can be related to other sampling points.

2--Preferred Methods

The preferred method of sampling an estuary depends on the hydrologic characteristics of the estuary and the objectives of the study; no single method is preferred.

3--Equipment

The equipment needed for collecting water-sediment samples from estuaries is dependent on the application. Single-point samples can be collected with Van-Dorn or Kemmerer-type water-sampling bottles of sufficient capacity to satisfy analytical requirements. A number of nearly simultaneous point samples throughout a vertical can be collected with Nansen-type bottles or a series of Van-Dorn or Kemmerer-type water-sampling bottles attached to an oceanographic line at predetermined intervals. Although Nansen-type bottles have limited capacity, they have the advantage, if equipped with reversing thermometers, of measuring the temperature of the sample at the instant of collection. Water-sampling bottles are relatively trouble free when used in saline waters because of their mechanical operation.

Discrete samples can be collected at any depth with pumps. Pumps have the advantage of supplying any required sample volume. However, because of the size of the intake line, supporting cable, need for external power source, and the inability, in most cases, to use a reel to hold the intake line, the use of pumps, particularly in deep water, can be cumbersome. Also, because of problems associated with electrical equipment and saline water, it is preferable to not use submersible pumps. An adequate pump for use in small boats can be designed using a peristaltic pump capable of delivering a varying flow rate.

A variety of nonstandard samplers are available for sampling estuaries. Stevens, Lutz, and Hubbell (1980) designed a collapsible bag sampler capable of collecting depth-integrated samples from deep estuaries. There are no preferred nonstandard samplers.

4--Procedures

The procedures for collecting water-sediment samples from estuaries are similar to those used for lakes and reservoirs. Depth of sampling should be selected based on the objectives of the study and the vertical distribution of the water-quality characteristics to be determined. For example, in a salt-wedge estuary the wedge normally is uniform, requiring fewer samples in the vertical than the overriding layer which normally has large salinity gradients. In mixed estuaries sampling at the top, middle, and bottom may be adequate. However, there is no single technique for selection of sampling depth that is applicable to all estuaries and for all purposes. In most cases a vertical profile needs to be developed to describe the water-quality characteristics of an estuary. Vertical salinity gradients vary with fresh-water inflow and tidal stage and may change rapidly; samples in the vertical should be collected simultaneously.

To collect simultaneous samples, the following general procedure is used regardless of the type of water-sampling bottle used: (1) sound the bottom to determine the depth; (2) select the sampling intervals based on criteria developed for the study; (3) reference sampling intervals to depth from the surface; (4) cock and attach a water-sampling bottle to the oceanographic cable at each interval; (5) place a messenger on the cable below the bottle and attach it to the tripping mechanism on the bottle--the bottom sampler needs no messenger; (6) repeat steps (4) and (5) until all bottles have been attached; (7) lower the cable until the top bottle is at the proper depth; (8) attach and drop a messenger to trip the top bottle--as this bottle is tripped, the messenger attached below it is released to trip the next bottle, and so on, until all have been tripped; and (9) retrieve the cable, detach each bottle, remove the sample, and process as required for analysis.

Sampling in estuaries can present significant safety hazards. Weather conditions such as fog, storms, or lightning and ship traffic can make sampling dangerous or impossible. Sampling schedules must be flexible enough to allow for adverse conditions.

Bed materials

Bed material is defined by the Office of Water-Data Coordination National Handbook, Chap. 3, P. 3-5 as "the sediment mixture of which the bed is composed." This differs from bedload in that bedload is sediment that moves by sliding, rolling, or bounding along or near the streambed (Leopold, Wolman, and Miller, 1964). From this perspective, the streambed is composed

Procedures

Churn Splitter

Determine the total volume of water-sediment samples needed by summing the volumes of all subsample containers required for the analysis schedule. Allow an additional volume of about 10 percent for spillage and filter losses. If the water-sediment sample is to be subsampled for analysis of "total" or "total recoverable" constituents, collect an additional 4 L of sample for the 14-L churn splitter, or 3 L for the 8-L churn splitter, to obtain representative subsamples.

Collect representative water-sediment samples of the streamflow using the sampling methods described above. Collect 1 L of sample at the first subsampling location to rinse the churn splitter before collecting the first sample. Quantitatively transfer each of the individual water-sediment samples collected into the churn splitter for compositing. Protect the churn splitter during freezing conditions to avoid formation of slush ice in the water-sediment mixture. When all of the individual water-sediment samples are in the churn splitter, place it on a support and place all of the labeled water-sediment subsample containers within easy reach.

Stir the composited water-sediment sample by raising and lowering the churning disc at a uniform rate of about 9 in. per second. The churning disc needs to touch the bottom of the tank and cover the entire depth of the sample without breaking the water surface on every stroke. High churning rates or breaking the water surface will entrain air in the water-sediment sample, which can change the concentration of dissolved gases, alkalinity, pH, and other characteristics. Inadequate churning rates can result in nonrepresentative subsamples. After stirring for about 10 strokes, the first subsample is withdrawn by placing a sample container under the spout and depressing the valve to fill the container while continuing stirring. Withdraw the remainder of the subsamples in a similar manner. Stirring needs to be continuous throughout the withdrawal of subsamples. If a break in withdrawal is unavoidable, the previous stirring rate needs to be reestablished before continuing withdrawals.

Withdraw subsamples to be analyzed for "total" and "total recoverable" constituents first. Allow the remaining water-sediment sample to settle, and then withdraw samples for filtration. When compositing and splitting have been completed, the churn splitter needs to be rinsed with distilled or demineralized water and properly stored.

Cone Splitter

Before using the cone splitter, field personnel need to inspect the unit. The cone-splitter housing and outlet parts should be smooth and symmetrical without any visible burrs or chips. Discharge tubes are to be the same length and securely attached to the outlet ports and extend into the subsample containers far enough to prevent spillage but not so far that the ends become submerged. The unit needs to be physically and chemically clean before use.

Place the required number of labeled subsample containers under discharge tubes. Discharge tubes can be combined to collect various combinations of the original water-sediment sample; however, when combining discharge tubes there must be no back pressure resulting from restriction of flow. Shake or stir the water-sediment sample for 10 to 15 seconds. Rapidly

APPENDIX F
EPA ERT SOP NUMBER 2006 – SAMPLING
EQUIPMENT DECONTAMINATION

EPA/540/P-91/005
OSWER Directive 9360.4-03
January 1991

COMPENDIUM OF ERT SURFACE WATER AND SEDIMENT SAMPLING PROCEDURES

~~X~~ Sampling Equipment Decontamination

Surface Water Sampling

Sediment Sampling

Interim Final

Environmental Response Team
Emergency Response Division

Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, DC 20460



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1.0 SAMPLING EQUIPMENT DECONTAMINATION: SOP #2006

1.1 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) describes methods used for preventing or reducing cross-contamination, and provides general guidelines for sampling equipment decontamination procedures at a hazardous waste site. Preventing or minimizing cross-contamination in sampled media and in samples is important for preventing the introduction of error into sampling results and for protecting the health and safety of site personnel.

Removing or neutralizing contaminants that have accumulated on sampling equipment ensures protection of personnel from permeating substances, reduces or eliminates transfer of contaminants to clean areas, prevents the mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

1.2 METHOD SUMMARY

Contaminants can be physically removed from equipment, or deactivated by sterilization or disinfection. Gross contamination of equipment requires physical decontamination, including abrasive and non-abrasive methods. These include the use of brushes, air and wet blasting, and high-pressure water cleaning, followed by a wash/rinse process using appropriate cleaning solutions. Use of a solvent rinse is required when organic contamination is present.

1.3 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

1.4 INTERFERENCES AND POTENTIAL PROBLEMS

- The use of distilled/deionized water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment

provided that it has been verified by laboratory analysis to be analyte free.

- An untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal water treatment system for mixing of decontamination solutions.
- Acids and solvents utilized in the decontamination sequence pose the health and safety risks of inhalation or skin contact, and raise shipping concerns of permeation or degradation.
- The site work plan must address disposal of the spent decontamination solutions.
- Several procedures can be established to minimize contact with waste and the potential for contamination. For example:
 - Stress work practices that minimize contact with hazardous substances.
 - Use remote sampling, handling, and container-opening techniques when appropriate.
 - Cover monitoring and sampling equipment with protective material to minimize contamination.
 - Use disposable outer garments and disposable sampling equipment when appropriate.

1.5 EQUIPMENT/APPARATUS

- appropriate personal protective clothing
- non-phosphate detergent
- selected solvents
- long-handled brushes
- drop cloths/plastic sheeting
- trash container
- paper towels
- galvanized tubs or buckets
- tap water

- distilled/deionized water
- metal/plastic containers for storage and disposal of contaminated wash solutions
- pressurized sprayers for tap and deionized/distilled water
- sprayers for solvents
- trash bags
- aluminum foil
- safety glasses or splash shield
- emergency eyewash bottle

1.6 REAGENTS

There are no reagents used in this procedure aside from the actual decontamination solutions and solvents. In general, the following solvents are utilized for decontamination purposes:

- 10% nitric acid⁽¹⁾
- acetone (pesticide grade)⁽²⁾
- hexane (pesticide grade)⁽²⁾
- methanol

⁽¹⁾ Only if sample is to be analyzed for trace metals.

⁽²⁾ Only if sample is to be analyzed for organics.

1.7 PROCEDURES

As part of the health and safety plan, develop and set up a decontamination plan before any personnel or equipment enter the areas of potential exposure. The equipment decontamination plan should include:

- the number, location, and layout of decontamination stations
- which decontamination apparatus is needed
- the appropriate decontamination methods
- methods for disposal of contaminated clothing, apparatus, and solutions

1.7.1 Decontamination Methods

All personnel, samples, and equipment leaving the contaminated area of a site must be decontaminated. Various decontamination methods will either physically remove contaminants, inactivate contaminants by disinfection or sterilization, or do both.

In many cases, gross contamination can be removed by physical means. The physical decontamination techniques appropriate for equipment decontamination can be grouped into two categories: abrasive methods and non-abrasive methods.

Abrasive Cleaning Methods

Abrasive cleaning methods work by rubbing and wearing away the top layer of the surface containing the contaminant. The following abrasive methods are available:

- **Mechanical:** Mechanical cleaning methods use brushes of metal or nylon. The amount and type of contaminants removed will vary with the hardness of bristles, length of brushing time, and degree of brush contact.
- **Air Blasting:** Air blasting is used for cleaning large equipment, such as bulldozers, drilling rigs or auger bits. The equipment used in air blast cleaning employs compressed air to force abrasive material through a nozzle at high velocities. The distance between the nozzle and the surface cleaned, as well as the pressure of air, the time of application, and the angle at which the abrasive strikes the surface, determines cleaning efficiency. Air blasting has several disadvantages: it is unable to control the amount of material removed, it can create contaminants, and it generates large amounts of waste.
- **Wet Blasting:** Wet blast cleaning, also used to clean large equipment, involves use of a suspended fine abrasive delivered by compressed air to the contaminated area. The amount of materials removed can be carefully controlled by using very fine abrasives. This method generates a large amount of waste.

Non-Abrasive Cleaning Methods

Non-abrasive cleaning methods work by forcing the contaminant off of a surface with pressure. In general, less of the equipment surface is removed using non-abrasive methods. The following non-abrasive methods are available:

- **High-Pressure Water:** This method consists of a high-pressure pump, an operator-controlled directional nozzle, and a high pressure hose. Operating pressure usually ranges from 340 to 680 atmospheres (atm) which relates to flow rates of 20 to 140 liters per minute.
- **Ultra-High-Pressure Water:** This system produces a pressurized water jet (from 1,000 to 4,000 atm). The ultra-high-pressure spray removes tightly-adhered surface film. The water velocity ranges from 500 m/sec (1,000 atm) to 900 m/sec (4,000 atm). Additives can enhance the method. This method is not applicable for hand-held sampling equipment.

Disinfection/Rinse Methods

- **Disinfection:** Disinfectants are a practical means of inactivating infectious agents.
- **Sterilization:** Standard sterilization methods involve heating the equipment. Sterilization is impractical for large equipment.
- **Rinsing:** Rinsing removes contaminants through dilution, physical attraction, and solubilization.

1.7.2 Field Sampling Equipment Cleaning Procedures

Solvent rinses are not necessarily required when organics are not a contaminant of concern and may be eliminated from the sequence specified below. Similarly, an acid rinse is not required if analysis does not include inorganics.

1. Where applicable, follow physical removal procedures specified in section 1.7.1.
2. Wash equipment with a non-phosphate detergent solution.
3. Rinse with tap water.
4. Rinse with distilled/deionized water.
5. Rinse with 10% nitric acid if the sample will be analyzed for trace organics.

6. Rinse with distilled/deionized water.
7. Use a solvent rinse (pesticide grade) if the sample will be analyzed for organics.
8. Air dry the equipment completely.
9. Rinse again with distilled/deionized water.

Selection of the solvent for use in the decontamination process is based on the contaminants present at the site. Use of a solvent is required when organic contamination is present on-site. Typical solvents used for removal of organic contaminants include acetone, hexane, or water. An acid rinse step is required if metals are present on-site. If a particular contaminant fraction is not present at the site, the nine-step decontamination procedure listed above may be modified for site specificity. The decontamination solvent used should not be among the contaminants of concern at the site.

Table 1 lists solvent rinses which may be required for elimination of particular chemicals. After each solvent rinse, the equipment should be air dried and rinsed with distilled/deionized water.

Sampling equipment that requires the use of plastic tubing should be disassembled and the tubing replaced with clean tubing, before commencement of sampling and between sampling locations.

1.8 CALCULATIONS

This section is not applicable to this SOP.

1.9 QUALITY ASSURANCE/ QUALITY CONTROL

One type of quality control sample specific to the field decontamination process is the rinsate blank. The rinsate blank provides information on the effectiveness of the decontamination process employed in the field. When used in conjunction with field blanks and trip blanks, a rinsate blank can detect contamination during sample handling, storage and sample transportation to the laboratory.

Table 1: Recommended Solvent Rinse for Soluble Contaminants

SOLVENT	SOLUBLE CONTAMINANTS
Water	<ul style="list-style-type: none"> • Low-chain hydrocarbons • Inorganic compounds • Salts • Some organic acids and other polar compounds
Dilute Acids	<ul style="list-style-type: none"> • Basic (caustic) compounds • Amines • Hydrazines
Dilute Bases -- for example, detergent and soap	<ul style="list-style-type: none"> • Metals • Acidic compounds • Phenol • Thiols • Some nitro and sulfonic compounds
Organic Solvents ⁽¹⁾ - for example, alcohols, ethers, ketones, aromatics, straight-chain alkanes (e.g., hexane), and common petroleum products (e.g., fuel, oil, kerosene)	<ul style="list-style-type: none"> • Nonpolar compounds (e.g., some organic compounds)

⁽¹⁾ - WARNING: Some organic solvents can permeate and/or degrade protective clothing.

A rinsate blank consists of a sample of analyte-free (i.e, deionized) water which is passed over and through a field decontaminated sampling device and placed in a clean sample container.

Rinsate blanks should be run for all parameters of interest at a rate of 1 per 20 for each parameter, even if samples are not shipped that day. Rinsate blanks are not required if dedicated sampling equipment is used.

1.10 DATA VALIDATION

This section is not applicable to this SOP.

1.11 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures.

Decontamination can pose hazards under certain circumstances even though performed to protect

health and safety. Hazardous substances may be incompatible with decontamination methods. For example, the decontamination solution or solvent may react with contaminants to produce heat, explosion, or toxic products. Decontamination methods may be incompatible with clothing or equipment; some solvents can permeate or degrade protective clothing. Also, decontamination solutions and solvents may pose a direct health hazard to workers through inhalation or skin contact, or if they combust.

The decontamination solutions and solvents must be determined to be compatible before use. Any method that permeates, degrades, or damages personal protective equipment should not be used. If decontamination methods pose a direct health hazard, measures should be taken to protect personnel or the methods should be modified to eliminate the hazard.

APPENDIX G

EPA REGION VIII SOP #1.6.5 – HANDLING OF INVESTIGATION-DERIVED WASTE

sites without dedicated sampling equipment). Samplers should be aware that the specific source of contamination will not be known if a contaminated rinsate sample was collected after numerous sampling and decontamination procedures. All of the locations associated with that rinsate blank may require resampling to identify the error.

1.6.5 Handling of Investigation-Derived Waste

1.6.5.1 Description of Investigation-Derived Waste

All waste materials generated during field investigations at potential hazardous waste sites are known as investigation-derived waste (IDW). Examples of IDW that may require treatment, storage, and disposal are as follows:

- Personnel protective equipment (PPE). This includes disposable coveralls, gloves, booties, respirator canisters, splash suits, etc.
- Disposable equipment (DE). This includes plastic ground and equipment covers, aluminum foil, conduit pipe, disposable bailers, pump tubing, etc.).
- Soil cuttings from drilling or hand augering operations.
- Drilling fluids (mud or water) used for drilling.
- Ground water obtained through well development or well purging.
- Decontamination fluids including spent solvent, detergent water and rinse water.

Some of these waste materials may be hazardous wastes and must be properly disposed in accordance with EPA regulations. The decision as to whether materials are hazardous should be based on the results of sample analyses.

The project leader or site manager should determine the appropriate handling approach upon designating the IDW as either RCRA hazardous or RCRA nonhazardous. (See U.S. EPA "Management of Investigation-Derived Wastes

During Site Inspections" EPA/540/G-91-009, 1991.) The project leader or site manager should use the decision tree shown in Exhibit G of this document (following the Section 1.0 tables) for help in selecting the best approach for IDW management, and identifying the steps that are involved in executing the approach. The decision tree summarizes basic elements of planning for IDW handling such as waste minimization, characterization, and management, and indicates when and how IDW should be handled on-site or disposed off-site. Management of IDW must also be described in detail in the QAPP or site-specific SAP.

1.6.5.2 Management of Non-Hazardous IDW

The management and disposal of non-hazardous IDW from hazardous waste sites should be addressed in the QAPP or site-specific SAP. If PPE and DE can be decontaminated and rendered nonhazardous, these wastes should be double-bagged, and deposited either in an industrial dumpster (on-site or at the EPA warehouse), or in a municipal landfill (RCRA Subtitle D facility). Non-hazardous IDW such as soil cuttings, drilling fluids, development or purge water, decontamination fluids, etc. should be left on-site unless other circumstances require off-site disposal. These circumstances include a state ARAR or a high probability of serious community concerns.

At all sites without adequate information to define the potential waste hazard, the IDW generated should be considered potentially hazardous until the results of testing indicate otherwise. All drilling, development and decontamination fluids and soil cuttings should be containerized on site until testing to verify that they are not contaminated.

The on-site handling options available when the results of analytical testing indicate that the IDW are nonhazardous, are listed below.

- For decontaminated PPE and DE:
 1. Double bag and deposit in an on-site dumpster, or in any municipal landfill.

2. Dispose of at the site's treatment or disposal unit.

- For soil cuttings:

1. Spread around the well.

2. Put into a shallow pit above the water table, within the area of contamination (AOC).

3. Dispose of at the site's treatment or disposal unit.

4. If the boring is less than 10 feet deep and did not penetrate the water table, cuttings may be placed back into the boring. All borings deeper than 10 feet or that encountered ground water shall be plugged and abandoned in accordance with the SOP included in a later section of this document.

- For drilling fluids and ground water (development and purge water):

1. Pour onto ground (from containers) downgradient from the well to allow infiltration.

2. Dispose of at the site's treatment or disposal unit.

- For decontamination and rinse fluids:

1. Pour onto ground (from containers) downgradient from the well to allow infiltration.

2. Dispose of at the site's treatment or disposal unit.

3. Evaporate dilute decontamination fluids on site if placed in an acceptable treatment container.

1.6.5.3 Management of Hazardous IDW

Disposal of hazardous or suspected hazardous IDW from hazardous waste sites should be addressed in the QAPP or site-specific SAP. IF IDW consist of hazardous soil cuttings that pose no immediate threat to human health and the

environment, then the soil cuttings can be left on-site within a delineated Area of Contamination (AOC) if they are containerized.

All soil borings that generate soil cuttings determined to be hazardous, must be plugged with cement grout from total depth to within two - three feet below land surface. Cuttings can not be placed in a borehole, regardless of depth, if analysis indicates that the cuttings are contaminated.

If on-site disposal is not feasible, and if the wastes are suspected to be hazardous, appropriate tests must be conducted to make that determination. If they are determined to be hazardous wastes, they must be properly contained and labeled. These hazardous wastes may be stored on the site for a maximum of 90 days before they must be manifested and shipped to a permitted treatment or disposal facility. If possible, the generation of hazardous IDW should be anticipated so that permits for the proper containerization, labelling, temporary storage, transportation, and disposal/treatment of these wastes can be arranged in accordance with USEPA regulations.

IDW should be disposed off-site at a permitted, RCRA subtitle C, TSD facility in the following situations:

- They are RCRA hazardous PPE and DE.
- They are RCRA hazardous soil cuttings that may pose a substantial risk if left on site.
- They are RCRA hazardous drilling fluids, ground water, or decontamination fluids.
- Leaving them on-site would create increased risks at the site.

Planners for off-site disposal of hazardous wastes should consider the following EPA guidelines:

- Incorporate a provision in the site access agreement form to inform the site owner that containerized IDW may be temporarily stored on-site

while awaiting pickup for off-site disposal. The agreement should also request the owner's cooperation.

- Initiate the bidding process for IDW testing, pick-up, and disposal. If there are any subcontracting needs in planning the off-site disposal, the means of disposal should be specified. Since RCRA hazardous IDW must go to RCRA hazardous waste disposal facilities that comply with the off-site policy, the site manager should obtain a list of available facilities. Each EPA Region maintains a list of RCRA hazardous TSD facilities that meet the conditions of the off-site policy. The site manager must also check the selected facility's compliance before arranging for IDW pick-up. If IDW are RCRA nonhazardous, the site manager must also check if the receiving RCRA nonhazardous waste facility complies with the off-site policy.
- Coordinate IDW generation with testing and pick-up. IDW samples should be collected in accordance with "Test Methods for Evaluating Solid Waste, SW-846," and shipped for RCRA tests (and other tests, if necessary) as early as possible during the site investigation. IDW need not be analyzed by a CLP laboratory. The site manager should use the laboratory services of the pickup and disposal subcontractor, obtain an EPA ID number and manifest form for RCRA hazardous IDW, and a bill of lading for RCRA nonhazardous IDW.
- Prepare adequate numbers and types of containers. Drums should be used for collecting small amounts of IDW. Larger amounts of soil and water can be contained in Baker tanks, poly tanks, and bins. PPE and DE should be collected in drums for disposal at a hazardous waste facility.
- Designate a storage area (either within the site's existing storage facility, existing fenced area, or within a temporary fence constructed for the site investigation). No unauthorized personnel may have access to the storage area. If a temporary storage facility is to be constructed, its location and size must be agreed upon with the site owner, and all construction materials should be delivered to the site before or on the first day of the site investigation.
- All RCRA hazardous wastes stored on site must comply with the 90 and 180 day storage requirements, as specified in RCRA regulations.
- All hazardous wastes generated at CERCLA sites must comply with requirements specified in the CERCLA and SARA regulations.

Hazardous investigation-derived waste should be kept to a minimum. Many of the above PPE and DE wastes can be deposited in industrial dumpsters if care is taken to keep them segregated from hazardous waste contaminated materials and environmental media. Disposable equipment and some PPE can sometimes be cleaned to render it nonhazardous. The volume of spent solvent waste produced during equipment decontamination can be reduced or eliminated by applying only the minimum amount of solvent necessary.

The reader is referred to "Management of Investigation-Derived Wastes During Site Inspections" (EPA/540/G-91/009) for further guidance on the management and disposal of investigation-derived waste.

1.6.6 Disposal of Samples or Physical Evidence

The disposal of samples or other physical evidence obtained during Region VIII EPA investigations is conducted on a case-by-case basis. CERCLA samples analyzed by laboratories under the Contract Laboratory Program (CLP), are disposed of in accordance with the contract specifications. No other samples, physical evidence, or any documentation associated with a criminal investigation shall be disposed without written permission from EPA's Office of Criminal Investigation, the Office of Regional Counsel, or the Department of Justice.

Before other samples or other physical evidence or documentation collected by or for the Region are disposed of, permission to dispose of the samples must be granted from the Project Manager responsible for the inspection or investigation. Signed documentation reporting the intention and permission to dispose of samples will be filed in the project files.

APPENDIX H

Modified Analysis Requests

Request for Quote (RFQ) for Modified Analysis

Date: April 18, 2008

Subject: Modification Reference Number: 1553.0
Title: SPLP for ICP-AES
Sample Matrix: Soil/Sediment
Fraction Affected: Metals
Statement of Work: ILM05.4

Purpose:

The Contractor Laboratory is requested to perform the following modified analyses under the Inorganic Statement of Work (SOW) ILM05.4, based on the additional specifications listed below. Unless specifically modified by this modification, all analyses, Quality Control (QC), and reporting requirements specified in SOW ILM05.4 remain unchanged and in full force and effect. The number of samples requested in this modification is not guaranteed.

Please note that accepting a modified analysis request is voluntary, and that the Laboratory is not required to accept the modified analysis. There will be no adverse effect to the Laboratory for not accepting the modified analysis request. However, once the Laboratory accepts the request for modified analysis, it shall perform the analysis in accordance with this modification and as specified in SOW ILM05.4.

The Laboratory is requested to review the modification described herein, determine whether or not it shall accept the requested modified analyses, and complete the attached response form. The Laboratory shall provide comments in response to the required changes in the designated area, in order to ensure that the modified analysis can be completed in accordance with the specifications described herein.

The requirements in the RFQ are as stated and the Government will reduce the line item price listed on the bid sheet for late deliverables at a rate of 5 percent per calendar day late, up to a maximum of 50 percent. The Government will treat noncompliant data and late data for Preliminary Results in accordance with the terms and conditions of the contract, using the price listed on the bid sheet as the basis for the calculation. The Laboratory should take this into account when submitting their quote.

Notice to Contractors: Acceptance of Modified Analysis samples will not count against the monthly capacity.

Modification to the SOW Specifications:

The contract Laboratory shall extract soil/sediment samples by Method SW-846 1312 [Synthetic Precipitation Leaching Procedure] using extraction fluid number two.

The Laboratory shall digest the SPLP extracts by preparation methods HW1 or MW1, and analyze for the Target Analyte List (TAL) by ICP-AES as indicated on the Traffic Report/Chain of Custody record.

The Laboratory shall analyze the SPLP extraction blanks as preparation blanks (PBW).

The Laboratory shall perform the Matrix Spike at the SOW specified levels.

The Laboratory shall report SPLP results as aqueous samples.

The Laboratory shall provide raw data [laboratory bench sheets, logs, notebook pages] for the SPLP procedure. This will include the initial determination of percent solids, amount of liquid (if any) separated from the solid phase, mass of solids material, and volume of extraction fluid used.

Reporting Requirements:

Hardcopy and electronic data reporting are required as specified per SOW ILM05.4. All hardcopy and electronic data shall be adjusted to incorporate modified specifications. This includes attaching a copy of the requirements for modified analysis to the SDG Narrative. If specific problems occur with incorporation of the modified analysis into the hardcopy and/or electronic deliverable, the Laboratory shall contact the DASS Manager within the Sample Management Office (SMO) at (703) 818-4233 or via email at CCSSUPPORT@fedcsc.com for resolution.

All samples and/or fractions assigned to an SDG shall be analyzed under the same Modified Analysis requirements as established in this memorandum. The Laboratory shall not include data from multiple Modified Analyses in one SDG.

The Laboratory shall include the Modification Reference Number 1553.0 on each hardcopy data form under the "NRAS No:" header appearing on each form as well as the "NRAS No." field on the Record type 21 of the electronic deliverable (if diskette deliverable is required). The Laboratory shall also document the Modification Reference Number and Solicitation Number on the SDG Coversheet.

Clarifications/Revisions to the RFQ for Modified Analysis:

Laboratory Name:**Laboratory Comments:**

Request for Quote (RFQ) for Modified Analysis

Date: April 18, 2008

Subject: Modification Reference Number: 1554.0
Title: ICP-MS with the Addition of Al, Ca, Fe, and Mg
Sample Matrix: Water
Fraction Affected: Metals
Statement of Work: ILM05.4

Purpose:

The Contractor Laboratory is requested to perform the following modified analyses under the Inorganic Statement of Work (SOW) ILM05.4, based on the additional specifications listed below. Unless specifically modified by this modification, all analyses, Quality Control (QC), and reporting requirements specified in SOW ILM05.4 remain unchanged and in full force and effect. The number of samples requested in this modification is not guaranteed.

Please note that accepting a modified analysis request is voluntary, and that the Laboratory is not required to accept the modified analysis. There will be no adverse effect to the Laboratory for not accepting the modified analysis request. However, once the Laboratory accepts the request for modified analysis, it shall perform the analysis in accordance with this modification and as specified in SOW ILM05.4.

The Laboratory is requested to review the modification described herein, determine whether or not it shall accept the requested modified analyses, and complete the attached response form. The Laboratory shall provide comments in response to the required changes in the designated area, in order to ensure that the modified analysis can be completed in accordance with the specifications described herein.

The requirements in the RFQ are as stated and the Government will reduce the line item price listed on the bid sheet for late deliverables at a rate of 5 percent per calendar day late, up to a maximum of 50 percent. The Government will treat noncompliant data and late data for Preliminary Results in accordance with the terms and conditions of the contract, using the price listed on the bid sheet as the basis for the calculation. The Laboratory should take this into account when submitting their quote.

Notice to Contractors: Acceptance of Modified Analysis samples will not count against the monthly capacity.

Modification to the SOW Specifications:

The contract Laboratory shall analyze water samples for the Target Analyte List (TAL), and the additional analytes Aluminum (Al), Calcium (Ca), Iron (Fe), and Magnesium (Mg), by ICP-MS as indicated on the Traffic Report/Chain of Custody record.

The Contract Required Quantitation Limits (CRQLs) and Matrix Spikes for the additional analytes are as follows:

Analyte	CRQL (ug/L)	Matrix Spike Level (ug/L)
Al	20	500
Ca	500	--
Fe	10	500
Mg	500	--

Please note that (--) indicates not required.

Method Detection Limit (MDL) studies for the additional analytes, by the preparation and analysis procedure used, are required. The MDLs shall be less than one-half the CRQLs listed above.

The Laboratory shall add Al, Ca, Fe, and Mg to the ICV/CCV solutions at appropriate levels, if they are not already present in the standards.

The Laboratory is not required to modify the CRQL Check Standard (CRI) solution.

The Laboratory shall add Al, Ca, Fe, and Mg to the LCSW at a concentration of 500 ug/L, if they are not already present.

Reporting Requirements:

Hardcopy and electronic data reporting are required as specified per SOW ILM05.4. All hardcopy and electronic data shall be adjusted to incorporate modified specifications. This includes attaching a copy of the requirements for modified analysis to the SDG Narrative. If specific problems occur with incorporation of the modified analysis into the hardcopy and/or electronic deliverable, the Laboratory shall contact the DASS Manager within the Sample Management Office (SMO) at (703) 818-4233 or via email at CCSSUPPORT@fedcsc.com for resolution.

All samples and/or fractions assigned to an SDG shall be analyzed under the same Modified Analysis requirements as established in this memorandum. The Laboratory shall not include data from multiple Modified Analyses in one SDG.

The Laboratory shall include the Modification Reference Number 1554.0 on each hardcopy data form under the "NRAS No:" header appearing on each form as well as the "NRAS No." field on the Record type 21 of the electronic deliverable (if diskette deliverable is required). The Laboratory shall also document the Modification Reference Number and Solicitation Number on the SDG Coversheet.

Clarifications/Revisions to the RFQ for Modified Analysis:

Laboratory Name:

Laboratory Comments:

Region 8 Laboratory Assignment Notification

Shipweek 05/04/2008

Case Number: 37402	Project Code:
Site: RICHARDSON FLAT TAILINGS	City, State: PARK CITY, UT
CERCLIS: UTD980952840	SSID: 94 Operable Unit: 00
Purpose: Remedial Action	Shipping Period: 05/05/2008 - 05/09/2008
Sampler, Sampling Co.: Sam Wilkes, Tetra Tech	
Comments: MA 1553.0 and 1554.1 Sol 503	

Laboratory

Datachem Laboratories, Inc. DATAC 960 West LeVoy Drive Salt Lake City, UT 84123 Phone: (801) 266-7700 Laboratory Contact: Roxanne Olson Sample Custodian: Meredith Edwards	Contract: EPW06054 Cost Lot: A
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Method	Samples Scheduled	Turnaround Time	Modified Analysis
ILM05.4 ICP-MS	45 WATER (Filtered) ICP Metals	21	1554.1
ILM05.4 ICP-AES	38 SOIL ICP Metals	21	1553.0
ILM05.4 ICP-MS	45 WATER ICP Metals	21	1554.1

Key					
ILM	Ag - Silver	Cd - Cadmium	filtered - samples filtered in the field	Na - Sodium	V - Vanadium
	Al - Aluminum	CN - Cyanide	Hg - Mercury	Ni - Nickel	Zn - Zinc
	As - Arsenic	Co - Cobalt	ICP Metals - TAL Metals without Hg	Pb - Lead	
	Ba - Barium	Cr - Chromium	K - Potassium	Sb - Antimony	
	Be - Beryllium	Cu - Copper	Mg - Magnesium	Se - Selenium	
	Ca - Calcium	Fe - Iron	Mn - Manganese	Tl - Thallium	
OLM/OLC	BNA - Semivolatiles	PEST - Pesticides/PCBs	VOA - Volatiles		
SOM	ARO - Aroclors	PEST - Pesticides	SVOA - Semivolatiles	SVSIM - SIM SVOA	TVOA - Trace Volatiles
	TVSIM - SIM TVOA	VOA - Volatiles			
ALL	PR - Preliminary Results				